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ACKNOWLEDGMENTS

The Executive Committee of the Society and its entire membership are greatly indebted to Colonel Willis E. Teale, District Engineer, Jacksonville, Florida District, Corps of Engineers, Department of the Army, and his associates for the fine interest they have displayed in the program of the Society, and for the splendid parts they have taken in it; also for his permission to dedicate this volume to him as an expression of appreciation on our part for the splendid work he has done and is doing in connection with the development of a highly coordinated water conservation and control program for Central and South Florida.

We are also greatly indebted to the U. S. Sugar Corporation for its gracious cooperation in allowing us the use of its spacious auditorium and many other facilities which contributed so greatly to the success of the meeting; likewise, to the Manager and his many assistants at the Clewiston Inn who handled the evening banquet in such a fine manner and, otherwise, made our members and their guests feel so much at home during their stay in Clewiston.

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COLONEL WILLIS E. TEALE
District Engineer, Jacksonville, Florida District,
Corps of Engineers, Department of the Army

COLONEL TEALE

Born in Muskegon, Michigan, Colonel Teale was graduated from the U. S. Military Academy in the class of 1917. He came to Jacksonville early in 1947 with a colorful and interesting career, both as a regular Army officer and as an engineer. During the war he organized and commanded the 38th Combat Engineer Regiment and served for two years as Chief Engineer of the U.S. Army Forces in Australia and of the Services of Supply of the Southwest Pacific area. Upon his return from overseas duty, he was named Commanding Officer, Albany Engineer Depot, and in June 1946, Commandant of the Army Engineer School, Fort Belvoir, Va. As Chief Engineer, Army Services of Supply in the Pacific area, Colonel Teale was awarded the Distinguished Service Medal for his superior performance of duties, and also the Legion of Merit for his outstanding services at the engineer school.

His first tour of overseas duty came during World War I in France with the 7th Engineers. In 1923, Colonel Teale continued his engineering studies and completed post graduate work at the Massachusetts Institute of Technology. For two and half years he was on duty as Secretary of the Mississippi River Commission with the Division Engineer in St. Louis, Missouri, where he won recognition in handling flood control works along the Upper Mississippi River.

Colonel Teale had other important assignments, including a two year tour of foreign duty with the American Battle Monuments Commission, Paris, France, assistant to the North Atlantic Division Engineer in New York, District Engineer at Mobile, Alabama, and Associate Professor of Mathematics, U. S. Military Academy.

As District Engineer of the Jacksonville District, Colonel Teale is in direct charge of all river and harbor and flood control work in peninsular Florida. It was under his direction that the Central and South Florida Plan for Flood Protection and Water Control, recently authorized by Congress, was developed and submitted to the Chief of Engineers.

Colonel and Mrs. Teale and their son reside in Jacksonville. Their daughter, Katherine, is attending Vassar College. Mrs. Teale is the former Miss Katherine Farr Brown of Cleburne, Texas.

LEWIS S. EVANS

THE NATIONAL WEED CONTROL PROGRAM

L. S. EVANS

The losses from weeds and undesirable plant growth are as great in their aggregate importance to the individual as those from insects and plant diseases combined. Weed control constitutes an almost ideal field for cooperative research. No weed control problem is limited to a single State and the local problems are so numerous that no one State can hope to investigate all of them adequately. The keen and widespread public interest in weed control naturally is pleasing to the research worker in this field. The avid interest of the farmer in herbicides is second only to his demand for mechanization. It would be difficult to overestimate what these chemicals imply to the future of agriculture. We are in the midst of further enormous growth in this field. All weed control activities are interdependent and in the process of rapid development. The first requisite is a critical review of the situation as a whole and a statement of the ultimate purpose of the program.

Research on the control of weeds is carried on by a number of agencies within the United States Department of Agriculture, each interested in a certain phase of the work. This discussion will deal primarily with the work of the Bureau of Plant Industry, Soils, and Agricultural Engineering. Weed research in this Bureau is conducted by the Divisions of Farm Machinery, Fruit and Vegetable Crops and Diseases, Forage Crops and Diseases, and Cereal Crops and Diseases, all in cooperation with State Experiment Stations in the various areas. The present research project was initiated in 1935 when a special appropriation was made by Congress for bindweed control investigations. It was organized as a project in the Division of Cereal Crops and Diseases of the above Bureau.

In December 1945 the Department of Agriculture was asked to cooperate with the Office of the Chief Engineers, War Department, on a study of the control of water hyacinth in the Gulf Coastal Area. This project was financed by the War Department.

In 1946 the Congress voted a modest appropriation for a study of the control of nut grass in the southeastern states and as a result work is now underway on this problem in Mississippi and Georgia.

In 1946 funds also were appropriated by the Congress for the study of the control of weeds on ditchbanks, in irrigation

—Agronomist, Division of Cereal Crops and Diseases, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, U. S. Dept. of Agriculture.

Editor's Note: Mr. Evans used a very extensive series of colored slides in presenting his lecture which, unfortunately, we are unable to reproduce in this published account.

canals, and reservoirs, and on irrigated lands of the West. This appropriation was obtained at the request of and with support from the Bureau of Reclamation of the Department of the Interior. Investigations in this problem are being conducted at field stations located in Arizona, Washington, Idaho, Utah, and Colorado.

With the passage of the Research and Marketing Act of 1946 new funds were made available for weed research work. A project entitled "To establish a cooperative national research program to develop practical methods and equipment for weed control" has been established. In addition to the personnel employed at Beltsville, field representatives in 15 states are now engaged in full time weed control research in cooperation with the various State Experiment Stations. In addition, close liaison is being maintained with the four regional weed control conferences organized throughout the United States. It is now believed that adequate coverage of the weed control problems of the country is being given within the limitations of the funds available. This is not meant to imply that all weed control problems are being attacked simultaneously.

THE APPROACH

The primary objective is the discovery of new facts and accurate interpretation of old ones though not necessarily for immediate practical ends. The keyword in integration. For example, integrated research would involve close liaison between the chemical-weed-killer men and those working in plant research and soil chemistry. Integrated operation means fitting the control to the weed, or the chemical to both crop and soil, or if this cannot be done to breed crop varieties resistant to the chemical. Integrated machinery concerns planning programs, education, and regulatory activities.

There is no lack of initiative on the part of the weed researchers in the field. Weed research is still in a fairly exploratory stage of development from the standpoint of experimental design and methods of analysis. A point of special significance is the present lack of standardized techniques and terminology.

The broad weed control research program includes (1) fundamental or basic studies, and (2) applied or agronomic phases. The fundamental studies will be common to two or more regions and will form a part of the national program of weed control investigations but may have broad consequences in related fields as well. The discovery of the growth regulator herbicides and other improved chemicals has shifted the emphasis on weed control investigations since 1944. These new chemicals are useful tools in any weed control program, but they do not fulfill all requirements. Some of the standard practices of weed control have been overshadowed by the advent of chemical control, but these older methods should not be discarded. Clean cultivation, short rotations, planting clean seed, and quick eradication of

new kinds of weeds that appear still represent reliable and effective methods in the never ending fight against weeds. Proper mowing, fertilization, and other details of pasture management will do much to alleviate the weed problem in pasture and range lands.

The general objective is to develop practical methods, materials, and equipment for the control of weeds. The headquarters of the national weed control program is at Beltsville, Maryland, near Washington, D. C. Basic research on herbicides and their effect on plants is underway at that location. Field investigations are established on a regional basis in cooperation with State Agricultural Experiment Stations and other agencies in each region. Chemical and physiological studies and field studies on competitive cropping, chemical weeding, pasturing, tillage, and other methods of control will be supported under this project in the several regions. Field work on the development of satisfactory mechanical, cultivating, spraying, flaming, electrical, and herbicide applying equipment is centered at Ames, Iowa, St. Paul, Minnesota and Stoneville, Mississippi. Agronomic, ecological, and mechanical investigations will first be undertaken on the major weeds of each region and the results will be made available to all cooperators. In addition to the cooperative work with the experiment stations within the continental United States plans are being made to take advantage of the year around growing conditions in Puerto Rico to permit the continual testing of new materials as to their herbicidal value. New chemicals will be screened in order to determine their herbicidal properties, chemical stability, toxicity to animals, inflammability and other characteristics. Studies will be conducted to establish and standardize indicator plants for evaluating herbicides.

A relatively small group of scientists have considered the basic weed control problems from the standpoint of deductive reasoning, while a much larger group approach the problem from the empirical or cut-and-try viewpoint. They have not yet reached common ground. Nevertheless the proper place exists for each approach. Empirical investigations have produced most of our information on weed control practices in current use. In this connection, it is pertinent to note that the direct assault in science is sometimes the least successful, while it is legitimate to keep searching for curative agents for weed pests it is quite certain in the long run that more will be gained by broadening the base of fundamental knowledge of weed behavior. This somewhat tedious spade work is now moving forward slowly in Beltsville and in other research institutions supported by public and private funds.

THE ACCOMPLISHMENTS

In a joint discovery by the personnel of our Bureau and the Bureau of Reclamation at the Denver Chemical Laboratory of the latter it was found that the carrier used in one of the pro-

prietary 2, 4-D compounds was toxic to aquatic weeds. When the carrier was analyzed the toxic constituent proved to be a coal tar naptha. Later a cheaper petroleum naptha was found to be just as effective and could be used at one tenth the cost of the chemical methods now in use. Extensive field scale trials of the new process are now underway in the water delivery systems of the irrigated southwest.

A different type of weed control is being studied in our nut grass investigations. Ethylene dibromide and chloropicrin, both highly volatile liquids, are being used as soil fumigants. Thus far they have been more effective though more expensive than any method of control by tillage or smother cropping. Nut grass cannot be eliminated simply by spraying with 2, 4-D because the effect generally does not extend below the basal bulb and the first tuber.

Considerable attention and emphasis has been given recently to the control of weeds in row crops by pre-emergence chemical treatment. Two methods have been employed. (1) Application of a selective herbicide to the soil at the time of seeding. The chemical in the soil kills weed seedlings but those of crop plants are uninjured. (2) Application of a general contact herbicide to a population of weed seedlings prior to the emergence of the crop seedling or prior to the seeding of the crops. Pre-emergence weed control is possible because as a rule only those weed seeds that are within the 1/4 to 1/2 inch of soil germinate. If the initial population of weed seedlings is destroyed without disturbing the soil and thus bringing more weed seeds near the surface, very few weeds will be present to interfere with the early growth of the seedling of the crop. Advocates of pre-emergence weed control recognize the fact that the early competition of weeds with crop seedlings is a factor of great significance.

Pre-emergence spraying with 2, 4-D under some conditions controls practically all kinds of annual weeds including grasses but there is much to be learned about its proper use. Soil applications of 2, 4-D at the rate of 2 pounds per acre effectively controlled weeds for a period of six weeks in crops such as corn, soybeans, lima beans, and peanuts. Dinitro compounds have been similarly successful on crops sensitive to 2, 4-D such as cotton and some vegetable crops. Pre-emergence weeding is more often hazardous on sandy soils than on clay soils because of the deeper percolation of the chemical into the soil. The rate of inactivation of the chemical by the soil may also be a factor in this case. In heavy soils the chemical does not reach deep planted crop seedlings in time to cause serious crop injury but may cause severe injury or death to the shallow germinating weed seeds. Research is continuing to determine the relationship of factors such as rainfall and soil moisture to the success of the treatment.

Ammonium trichloroacetate has shown promise as an effective perennial grass killer when applied at rates of from 100 to 150

lbs. per acre. When applied to the soil this chemical has a somewhat selective effect on the perennial grasses but when applied as a foliage spray it behaves as a non-selective herbicide. Selected fractions of the aromatic petroleum compounds have been found to be considerably more effective in controlling Bermuda grass and Johnson grass in the irrigated sections of the outh west than has ordinary diesel oil. These materials are now being used extensively for the control of undesirable vegetation on irrigation ditchbanks. These materials are non selective in their action and since they serve only as contact killers, 1 to 5 applications may be required to completely destroy established stands of the perennial grasses. Diesel oil, which has commonly been used in many sections of the West for the control of unwanted vegetation, is now being fortified with such compounds as pentachlorophenol or the dinitro phenols. The addition of these extenders may be expected to alleviate the present oil shortage to some degree.

A significant development in weed control has been low volume applications of spray. Whereas formerly we thought in terms of 100 to 300 gallons of liquid applied to the acre we now are using successfully volumes as low as 3 gallons (or even less) per acre. Low volume applications have been made possible by improvement in equipment, particularly nozzles, and by taking advantage of the translocating characteristic of 2, 4-D and other growth regulating herbicides. Low volume applications are especially valuable in areas where water is scarce and where hauling and refilling add materially to the cost of application.

THE PROSPECT

Three points can be made about weed control as a science. It is the youngest science although actually, in a crude form, it stretches back into antiquity. It is in the midst of further enormous growth and it is in a crisis that reflects the preoccupation of the average American with the idea of "pill" farming. In some cases weed control is the last bottleneck to the complete mechanization of some farming operations, notably cotton and sugarcane culture. The weed researchers began to appear in numbers in 1936 but as a distinct class his origin began in 1944 with the premature announcement of 2, 4-D. These are the challenging facts which provide a sense of urgency underlying the whole profession. Chemical weed control is not a substitute for good farming—it is a part of good farming.

Spectacular growth is nothing new in the sciences. The War prepared the ground for the great efflorescence in other scientific fields and its surprising proliferation in our own. The days of improvisation are not gone but laymen are beginning to ask pertinent questions about the "why" of things. While it is true that we don't have to know the cause of fire before efforts are undertaken to extinguish it, we cannot accurately appraise our

accomplishments in weed control as long as we are troubled by the lack of basic research. We are still too engrossed with the details to be able to explore the field with the objective and leisurely contemplation which is accepted as the measure of the true scientist.

We are close to something new and revolutionary and universally important. The underlying idea of non-cultivation is not new—but now for the first time through the use of chemicals we have available means of controlling weeds without resorting to some of the inefficient and disadvantageous tillage practices which have prevailed through generations. The new system may not be foolproof but the errors, for the most part, are self-correcting. The inherent possibilities have not yet been realized but they are limited only by the spontaneity, ingenuity, and original creativeness of the research workers concerned.

SYMPOSIUM I

THE CONTROL OF WATER PLANTS FROM THE STANDPOINT OF WATER MANAGEMENT AND NAVIGATION IN THE LAKES, RIVERS AND CANALS OF THE SOUTH

THE GENERAL CHARACTERISTICS OF THE PRINCIPAL PLANTS INVOLVED

ERDMAN WEST

There are many plants in the South that inhabit navigable waters, their margins and their tributaries. If we are to discuss the problem of their control, we must know something about the characteristics of these plants. It is not necessary to list, let alone discuss, every species that might be found in this environment. In the mild climate of this area, there are so many kinds that there would be little time for any discussion of their control. Moreover, many of them are so rare or local that they are of very minor importance. It will be more practical from all standpoints to confine our consideration to the more numerous and hence more important species. If we divide these according to habitat, we can simplify our problem still further. I believe control measures are likely to follow this sort of classification rather closely too. I would like to put them into three categories and call them floaters, bankers and sinkers.

FLOATERS

The first division will be called "floaters" because they float on the surface of the water and grow without the necessity of any attachment to the soil. Normally, they float freely and move with the surface currents of the water. In shallow areas or margins their roots may anchor them in the mud. The most ubiquitous is, of course, the common introduced water hyacinth It has long been the most pestiferous plant in navigable waters and millions of dollars have been spent, more or less futile, in attempting its control. The discovery and use of 2, 4 D weed killer has changed this picture very materially. Water hyacinth floats by means of the inflated petioles or stalks of its leaves and multiplies rapidly by offshoots. How much reproduction occurs from seeds is not well known.

A native floating plant, water lettuce, has many of the general characteristics of water hyacinth, but it does not multiply nearly as rapidly. Each plant bears many flat, pale green, leaves in the form of a rosette. The flowers are small, inconspicuous, greenish-white, hairy and funnel shaped.

Another native aquatic, frogbit, is far less common but may

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[1]—Botanist, Florida Agricultural Experiment Station, Gainesville

Figure 1.—FLOATERS—This tremendous growth of water hyacinths is typical of the "Floater" group of water weeds. The Hillsboro Canal is under this heavy mat and, of course. greatly reduced in its capacity to handle drainage and irrigation waters. The measuring stick at the left, which is held at the water's level, shows the height of the plants to be nearly 3 feet. Photo taken in front of the Everglades Experiment Station looking towards Belle Glade on October 24, 1935.

be locally abundant. The leaves are shaped like water hyacinth leaves, but the base of the leaf blade is spongy and the leaf stalk is slender. The flowers are small and white, resembling small spiders. It multiplies by producing offshoots or lateral stems 4 to 6 inches long. Large colonies are often inter-connected by these horizontal and slightly submerged stems. At some seasons of the year, numerous seeds are released.

In densely shaded areas the floating fern may cover considerable areas, in patches as much as 20 feet across. The vegetative leaves float on the surface of the water and produce young plants along their margins. Even small pieces broken off may drift away and develop a new plant. The whole plant is brittle and easily broken up.

Among the smaller plants are the duckweeds and floating fern allies. Any one of these, alone or in combination, may cover the surface with the small plants individually less than one-fourth inch across. Spirodela and Lemna are the common native duckweeds found nearly everywhere. The fern allies are introduced plants called Azolla and Salvinia. The character that makes these plants particularly obnoxious is their small size. Rakes and most nets are useless because the plants slip through the meshes so that they cannot be removed mechanically.

Figure 2.—BANKERS—The heavy growth of Para grass extending from both banks of the Hillsboro Canal to a point of nearly closing it is a good example of this type of water weed. Photo taken in Belle Glade from the main bridge looking towards Lake Okeechobee, June, 1948.

BANKERS

The second division of aquatic plants with which we are dealing is called the "bankers" because they must have their roots in the soil of the banks or margins of the body of water invaded. Their stems are usually hollow or inflated so that they float on or near the surface and may extend out ten or more feet from the bank where the root-system is embedded. They often extend out from both banks and completely cover canals or small streams.

One of the most important of the bankers, at least here in the Everglades, is the introduced Para grass. This grass grows vigorously on moist soil and produces great numbers of long runners or horizontal stems. On land, they root at every joint that touches the soil but on the water they float near the surface and increase in length.

There are several native grasses that act in much the same manner. Fall panic grass and swamp grass are two of the larger growing kinds that may extend 6 to 8 feet from the bank. Two others that are much less vigorous in growth are creeping paspalum and water grass.

Another vigorous and prolific plant in this category is water pennywort. This aquatic with round leaves attached at the center has inflated stems and leaf stalks which enable it to float easily. In quiet water these floating runners may extend 20 feet from the bank or point of attachment. Seeds are produced in

great quantities and float readily to new locations. Newly invaded ponds or streams are quickly populated.

An introduced weed has shown itself to be potentially the most dangerous of this group. This is the dreaded alligator weed. It has become established in only a few places in Florida, and so far has not occupied much area in this State but elsewhere it has proved to be a major pest. It has narrow leaves and terminal heads of small silvery-white flowers.

One of the smartweeds, portorican, is a valuable food plant for ducks but it can also extend out from banks or islands and cover considerable areas of water too.

Watershield with its oval leaves and jelly-covered stems is not a very vigorous grower but is often a pest in lakes.

An introduced aquarium plant known as parrot's feather is a vigorous grower. It is frequently thrown out by gold fish growers when it becomes too abundant in their pools or aquaria. Such discarded material can quickly create a hazard if it is thrown into a stream or other body of water. It has very finely cut bluish-green leaves.

SINKERS

The third division has been named "sinkers." These, strictly speaking, do not sink but they do have their roots in the bottom of whatever body of water they invade. They constitute the most insidious of the pests because they are submerged and hence inconspicuous but they nevertheless greatly impede water flow and slow down navigation.

One of the most common in this group is coontail, incorrectly called moss or coontail moss(it is not a true moss). It forms large plumy or ball-shaped masses of stems and narrowly segmented leaves. It is dull, dark green in color but the growing tips are often pinkish.

In some areas, naiads are more common. This is more grass-like with thin wiry stems and short narrow leaves, but it grows to great length and covers vast areas of bottom with a dense growth. It is very common in lakes and canals.

In shallow water, the pondweeds can become pests. Some of these invade brackish water as well as fresh. They vary much in leaf size and shape but all species are characterized by cone-like flower clusters.

Some other submerged aquatics such as bladderworts, cabomba and elodea are locally common and troublesome.

SUMMARY

This is a brief consideration of the plants involved in the management of water for navigation, conservation or other purposes. In general, the habits of the plants as groups seem more important than the botanical characteristics of the species. As tolerances or immunity to specific chemicals become more apparent, certain species may become more important or demand

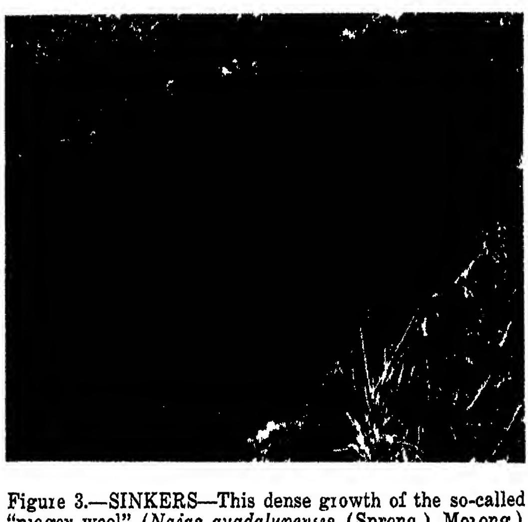

Figure 3.—SINKERS—This dense growth of the so-called "nigger wool" (*Najas guadalupensis* (Spreng.) Morong.) that practically fills the entire cross section of these drainage canals is a good example of the submerged or "Sinker" type. It is even worse than a hyacinth cover because it almost stops all flow and actually blocks the canal until removed. Above—in the Clewiston area; Below—in the Davie area under pumpdown conditions with flow lines showing along the surface of the weed.

special treatment, but for the present they can be treated in the groups we have outlined. The scientific names of the weeds referred to above are listed below under the three groupings which have been adopted for convenience in discussion.

FLOATERS

Water hyacinth	*Eichornia crassipes* Mart.
Water lettuce	*Pistia stratiotes* L.
Frogbit	*Limnobium spongia* (Bosc.) L. C. Rich.
Floating fern	*Ceratopteris pteridoides*
Duck weeds	*Lemna* spp.

BANKERS

Para grass	*Panicum purpurascens* Raddi
Fall panic grass	*Panicum dichotomiflorum* Michx.
Swamp grass	*Panicum paludivagum* H. & C.
Water grass	*Hydrochloa* sp.
Creeping paspalum	*Paspalum repens* Berg.
Water pennywort	*Hydrocotyle* spp.
Alligator weed	*Achyranthes philoxeroides* (Mrt.) Standley
Portorican smartweed	*Polygonum portoricense* Bertero
Watershield	*Brasenia schreberi* Omel.
Parrot's feather	*Myriophyllum proserpinacoides* Gill.

SINKERS

Coontail	*Ceratophyllum demersum* L.
Naiad	*Najas guadalupensis* (Spreng.) Morong.
Pondweeds	*Potamogeton* spp.
Bladderworts	*Utricularia* spp.
Cabomba	*Cabomba caroliniana* A. Gray
Elodea	*Anacharis* spp.

DISTRIBUTION OF WATER HYACINTH IN FLORIDA

JAMES A. HAMMACK[1]

JAMES A. HAMMACK

The Jacksonville District of the Corps of Engineers recently completed a survey of the entire State of Florida to determine the extent and concentration of the hyacinth and other marine vegetable growth. Authority for this investigation is contained in a resolution of the Committee on Rivers and Harbors of the House of Representatives adopted 6 February 1945.[2]

A conference of the South Atlantic Division Committee on Hyacinth Eradication and Control was held in Atlanta, Ga., 11 and 12 February 1946. It was decided that aerial photos would be carried on observation flights at low altitude and detailed data recorded on the photos as far as practicable.

An inventory was taken of aerial photographs in the District Engineer's files and it was found that there were about 22,000 square miles to a scale of 1:20,000 to 24,000, also 7,800 square miles at 1:40,000. From commercial sources and various governmental agencies, photographs of the remaining part of Florida with the exception of a part of one county were obtained. In view of the large number of individual photographs, the overlapping coverage, and the anticipated difficulty in handling these small individual photographs in an airplane, it was decided to assemble the photographs into mosaics and photostat them to a uniform 1:20,000 scale on sheets 18" x 24", accordion folded and

[1]—Engineer, Corps of Engineers, U. S. Engineer Office, Jacksonville.

[2]—COMMITTEE ON RIVERS AND HARBORS, HOUSE OF REPRESENTATIVES U. S., WASHINGTON, D. C., RESOLUTION

Be it resolved by the Committee on Rivers and Harbors of the House of Representatives, United States, That the Board of Engineers for Rivers and Harbors created under Section 3 of the River and Harbor Act, approved June 13, 1902, be, and is hereby requested to review the reports on Water Hyacinth Obstructions submitted in House Document Numbered 91, 55th Congress, 3d Session, with a view to determining (a) whether any expansion of the scope of operations, or any change in the method now employed, for exterminating and removing the hyacinth plants and other marine vegetable growths from the waters of Louisiana, and such other States as

TABLE 1—DISTRIBUTION OF ALLIGATOR WEED AND PICKEREL WEED IN FLORIDA, BY COUNTIES

County	Alligator weed (acres)	Pickerel weed (acres)	County	Alligator weed (acres)	Pickerel weed (acres)
1 Alachua	0	907	35 Lake	0	8
2 Baker	0	2	36 Lee	0	1
3 Bay	0	0	37 Leon	0	586
4 Bradford	0	24	38 Levy	0	6
5 Brevard	0	137	39 Liberty	0	1
6 Broward	0	12	40 Madison	0	294
7 Calhoun	0	0	41 Manatee	0	180
8 Charlotte	0	33	42 Marion	0	40
9 Citrus	0	0	43 Martin	0	0
10 Clay	0	74	44 Monroe	0	0
11 Collier	0	9	45 Nassau	1	26
12 Columbia	0	9	46 Okaloosa	0	0
13 Dade	0	11	47 Okeechobee	0	1
14 DeSoto	0	14	48 Orange	0	1
15 Dixie	0	0	49 Osceola	0	1,414
16 Duval	19	2	50 Palm Beach	0	20
17 Escambia	0	0	51 Pasco	0	122
18 Flagler	0	37	52 Pinellas	0	11
19 Franklin	1	1	53 Polk	0	1
20 Gadsden	0	0	54 Putnam	0	45
21 Gilchrist	0	0	55 St. Johns	2	9
22 Glades	0	148	56 St. Lucie	0	1
23 Gulf	0	0	57 Santa Rosa	0	0
24 Hamilton	0	12	58 Sarasota	0	53
25 Hardee	0	427	59 Seminole	0	213
26 Hendry	0	1	60 Sumter	0	0
27 Hernando	0	109	61 Suwannee	0	30
28 Highlands	0	319	62 Taylor	0	523
29 Hillsborough	0	381	63 Union	0	3
30 Holmes	0	1	64 Volusia	1	58
31 Indian River	0	1	65 Wakulla	0	113
32 Jackson	0	3	66 Walton	0	0
33 Jefferson	0	867	67 Washington	0	61
34 Lafayette	0	2			
			Total	24	7,364

so marked as to permit rapid handling in a small space while flying. Each photostated sheet was numbered and in the margins the numbers of the surrounding sheets were indicated. The sheets were assembled by counties and index maps prepared for

are affected, is advisable at this time; (b) the nature and extent of the various public benefits that would accrue from such extermination and removal, and (c) the amount of local cooperation that may be warranted by reason of the local benefits.

Be it further resolved that this action be taken with the view of determining the estimated cost of permanently eliminating the hyacinth plants and other marine vegetable growths from these streams, and that the cooperation of the Fish and Wildlife Service of the Department of the Interior, and of the Department of Agriculture and the United States Public Health Service be solicited, since the aforementioned obstruction of such streams affects the fishing industry, agriculture and health conditions.

Adopted February 6, 1945. Attest: J. H. McGann,
Clerk.

each county showing the coverage of each photostated sheet on a 1-page map of the county.

An effort was made to find some organization that had completed a large-scale reconnaissance survey of this nature from an airplane, but none was found. Through the courtesy of a local flying service a test flight was made to determine conditions which would be encountered and the type of flying equipment best suited for aerial observers. It was decided that a light, high-wing monoplane, with side-by-side seating arrangement, was desirable. Such a seating arrangement permits the pilot and observer to use the same set of aerial maps to maintain a predetermined flight pattern. It was specified that the plane would have a cruising speed of 100 miles per hour, capable of maintaining safe flying speed at 60 miles per hour. The view from a plane of this type is excellent, affording a wide angle of vision approaching 180 degrees.

Both aerial observers selected from the personnel of the District Office had many hours of contact flying over this State. Although ability to fly was unnecessary, as a plane with pilot was contracted for, it was considered desirable that the observer be able to quickly and readily spot and keep his position and direction on the photos. Further, it was thought that persons used to flying in light planes would be less inclined to be bothered by its motions on bumpy air.

Aerial observation was commenced June 3, 1946, and continued until terminated September 17, 1946, in compliance with a Presidential Economy Order. Work was resumed June 4, 1947, and observation from single-engine plane completed July 30, 1947. A total of about 46,000 square miles was covered in a single-engine plane in about 410 hours' flying time. The Everglades part of the State was covered using a twin-engined plane for safety, as recommended by the Civil Aeronautics Authority. In all, a total of about 59,000 square miles of survey was completed August 7, 1947, in 486 hours' flying time, at an average of about 120 square miles per hour. This coverage was made possible by good mechanical performance of the planes and close cooperation of the pilots and Government observers. Much of the observation was made at an elevation of about 500 feet, with some at higher and lower altitudes. The location and density of infestation were marked on the photostat maps as the area was traversed by the plane.

The aerial survey work was checked by ground reconnaissance using two parties of two men each in automobiles carrying the photostats marked by the aerial observers.

Results of this survey are shown on these maps and tabulations of findings are included on these tables. Areas are ex-

TABLE 2—DISTRIBUTION OF WATER HYACINTH IN FLORIDA BY COUNTIES SHOWING ACCESSIBILITY, CONCENTRATION, AND WATERWAY USE

County	Accessibility			Concentration				Waterway Use				Total water hyacinth
	Easy (acres)	Difficult (acres)	Inaccessible (acres)	Sparse (acres)	Moderate (acres)	Dense (acres)	Very dense (acres)	Navigable (acres)	Non-Navigable (acres)	Drainage Ditches (acres)	Lakes and Ponds (acres)	(acres)
1. Alachua	262	635	899	540	46	1,069	141	1	8	108	1,679	1,796
2. Baker	0	0	0	0	0	0	0	0	0	0	0	0
3. Bay	0	0	0	0	0	0	0	0	0	0	0	0
4. Bradford	2	0	0	0	2	0	0	0	0	0	2	2
5. Brevard	246	53	4	57	36	18	192	0	164	80	59	303
6. Broward	684	0	150	8	96	390	340	0	48	786	0	834
7. Calhoun	0	0	0	0	0	0	0	0	0	0	0	0
8. Charlotte	36	0	148	5	49	125	5	0	27	20	137	184
9. Citrus	258	1,866	0	0	982	1,142	0	344	0	0	1,780	2,124
10. Clay	121	32	45	0	117	71	10	121	77	0	0	198
11. Collier	219	222	2	3	8	36	396	0	0	0	443	443
12. Columbia	0	795	14	38	76	616	79	10	0	0	799	809
13. Dade	121	0	0	2	13	42	64	0	0	116	5	121
14. DeSoto	341	401	291	0	86	67	880	0	1,032	1	0	1,033
15. Dixie	50	19	142	6	192	13	0	203	6	0	2	211
16. Duval	245	8	0	8	74	127	44	237	8	0	8	253
17. Escambia	0	0	0	0	0	0	0	0	0	0	0	0
18. Flagler	115	43	20	0	165	13	0	33	5	15	125	178
19. Franklin	0	25	0	1	0	24	0	0	25	0	0	25
20. Gadsden	290	35	0	0	325	0	0	0	0	0	325	325
21. Gilchrist	0	0	20	0	20	0	0	0	20	0	0	20
22. Glades	373	10	1,271	630	139	762	123	0	509	482	663	1,654
23. Gulf	0	2	0	2	0	0	0	0	2	0	0	2
24. Hamilton	0	6	0	0	0	6	0	0	0	0	6	6
25. Hardee	60	6	411	67	11	335	64	0	136	6	335	477
26. Hendry	73	0	98	3	64	92	12	0	0	158	13	171
27. Hernando	12	284	36	0	169	163	0	178	0	0	154	332
28. Highlands	1,946	1,182	3,841	1	1,969	2,801	2,198	0	6,645	114	210	6,969
29. Hillsborough	877	59	810	62	109	1,162	413	406	620	67	653	1,746
30. Holmes	0	0	0	0	0	0	0	0	0	0	0	0
31. Indian River	115	0	2	1	3	44	69	73	40	4	0	117
32. Jackson	0	0	0	0	0	0	0	0	0	0	0	0

33. Jefferson	0	4	0	0	4	0	0	0	0	0	4	4
34. Lafayette	0	0	0	0	0	0	0	0	0	0	0	0
35. Lake	488	88	1,084	79	1,222	359	0	338	707	0	615	1,660
36. Lee	43	0	0	6	1	15	21	0	14	29	0	43
37. Leon	73	87	0	48	112	0	0	0	23	0	137	160
38. Levy	681	39	285	634	339	32	0	703	47	0	255	1,005
39. Liberty	0	0	0	0	0	0	0	0	0	0	0	0
40. Madison	0	7	0	1	4	1	1	0	4	0	3	7
41. Manatee	547	0	36	21	370	162	30	0	360	14	209	583
42. Marion	233	131	0	17	172	114	61	3	75	83	203	364
43. Martin	106	0	1	6	13	76	12	10	2	52	43	107
44. Monroe	0	0	0	0	0	0	0	0	0	0	0	0
45. Nassau	88	13	20	10	36	37	38	101	19	0	1	121
46. Okaloosa	0	0	0	0	0	0	0	0	0	0	0	0
47. Okeechobee	1,491	1,399	4,417	0	5,338	1,804	165	0	6,467	803	37	7,307
48. Orange	1,456	140	153	142	159	261	1,187	0	286	26	1,437	1,749
49. Osceola	199	10	1,723	99	500	225	1,108	0	1,353	42	537	1,932
50. Palm Beach	2,842	470	2,566	1,351	1,746	2,484	297	0	37	2,561	3,280	5,878
51. Pasco	690	286	1,532	7	207	2,051	243	0	1,818	0	690	2,508
52. Pinellas	12	92	0	1	1	92	10	0	1	0	103	104
53. Polk	5,828	631	3,888	52	1,745	3,296	5,254	0	2,937	127	7,283	10,347
54. Putnam	1,177	328	140	31	993	621	0	1,186	133	23	303	1,645
55. St. Johns	103	37	28	12	10	134	12	126	32	8	2	168
56. St. Lucie	447	0	84	3	34	61	433	0	269	262	0	531
57. Santa Rosa	0	0	0	0	0	0	0	0	0	0	0	0
58. Sarasota	534	0	75	7	64	520	18	0	352	14	243	609
59. Seminole	695	7	251	6	59	522	366	106	343	0	499	953
60. Sumter	783	981	0	0	1,764	0	0	1,715	0	24	25	1,764
61. Suwannee	0	28	0	0	15	13	0	0	0	0	28	28
62. Taylor	0	0	6	0	2	4	0	0	1	0	5	6
63. Union	0	0	0	0	0	0	0	0	0	0	0	0
64. Volusia	1,906	348	821	0	2,273	799	3	837	411	88	1,739	3,075
65. Wakulla	0	0	0	0	0	0	0	0	0	0	0	0
66. Walton	0	0	0	0	0	0	0	0	0	0	0	0
67. Washington	0	0	0	0	0	0	0	0	0	0	0	0
Total	26,868	10,809	25,314	3,967	21,934	22,801	14,289	6,731	25,068	6,113	25,079	62,991

Note—The above information is based on aerial and ground reconnaisance of the entire State of Florida, conducted in 1946 and 1947.

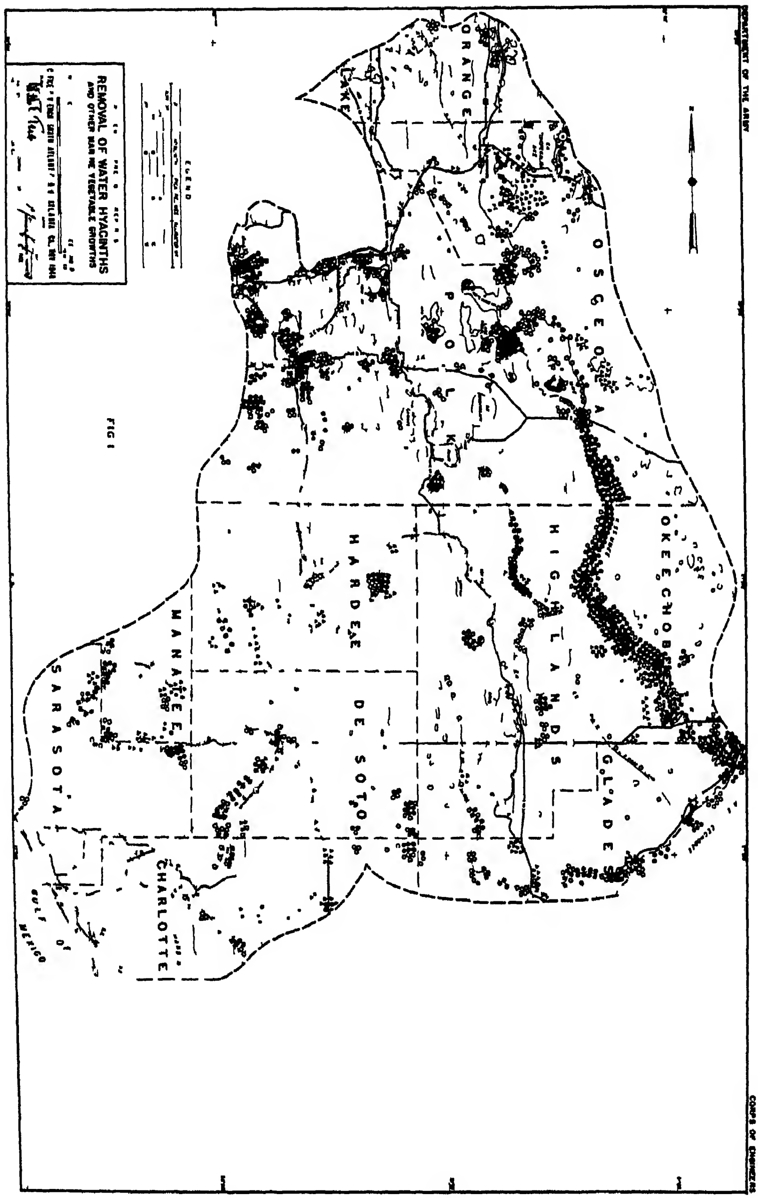

Figure 1.—Sheet No. 8 of 13 sheets covering hyacinth survey of the Southeast (10 sheets for Florida) by the U. S. Engineer Division Office in Atlanta and District Office in Jacksonville. The Kissimmee Valley is conspicuous for the heavy growths that are to be observed up and down its broad and irregular channelway.

TABLE 3—DISTRIBUTION OF WATER HYACINTH, PICKEREL WEED, AND ALLIGATOR WEED, BY WATERSHEDS

	Hyacinth	Pickerel weed	Alligator weed
St. Johns River and related areas	9,504	569	22
Suwannee River	1,363	137	0
St. Marys River	2	16	0
Nassau River	142	13	1
Total above rivers and related areas	1,507	166	1
Apalachicola River	27	5	0
Ochlochnee River	485	68	1
St. Marks River	3	1,380	0
Aucilla River	9	265	0
Econfina River	0	153	0
Fenholloway River	2	478	0
Steinhatchee River	3	42	0
Total above rivers and related areas	529	2,391	1
Choctawhatchee River	0	62	0
Perdido River	0	0	0
Escambia River	0	0	0
Black Water River	0	0	0
Yellow River	0	0	0
Total above rivers and related areas	0	62	0
Oklawaha River	3,978	934	0
Waccasassa River	256	6	0
Whithlacoochee River	7,442	51	0
Total above rivers and related areas	11,676	991	0
Hillsboro River	2,116	548	0
Alafia River	1,428	36	0
Manatee River	181	30	0
Total above rivers and related areas	3,725	614	0
Kissimmee River	21,113	1,762	0
Peace River	6,478	676	0
Total above rivers and related areas	27,591	2,438	0
Caloosahatchee River and lower west coast	1,626	90	0
Lower east Coast and Everglades	6,833	43	0
Grand total of Florida	62,991	7,364	24

pressed in acres classified according to density, using the following terms:

(a) Sparse—more open water than hyacinth.
(b) Moderate—less open water than hyacinth.
(c) Dense—no open water but not compacted.
(d) Very dense—compacted.

Also shown are other classifications, such as accessibility to presently used mechanical equipment and waterway use.

The total area of hyacinths as computed from the survey in the State of Florida is 62,991 acres. Of this amount, 3,967 acres

were classified sparse; 21,934 acres moderate; 22,801 acres dense; and 14,289 acres very dense.

Among the more heavily infested waterways of the State are the Kissimmee, St. Johns, Withlacoochee, and Peace Rivers, with their tributaries. Hyacinths were found in 55 of 67 counties of Florida. Over one-half of the hyacinths in Florida were found in the following five counties: Polk, Okeechobee, Highlands, Palm Beach, and Volusia.

Of course, it will be appreciated that the area and location of hyacinths vary with the wind, floods, weather, and other factors, such as propagation. So the area, location, and density of hyacinths, if resurveyed today, would unquestionably differ somewhat from that made in 1946-47 or from a survey made say 2 years hence. It is believed the information obtained is accurate and adequate for use in the forthcoming report of the South Atlantic Division Committee scheduled for completion November 1, 1948.

In Figure 1 is to be found a very small scale reproduction of Map No. 8 as typical of the 9 required to cover the whole State for the purposes of this survey. Inasmuch as No. 8 covers the Kissimmee River from its upper reaches to Lake Okeechobee, it is about as typical as any of them and at the same time represents about as many hyacinths.

ALLIGATOR WEED—A NEW MENACE FOR FLORIDA

L. S. EVANS*

Alligator weed, sometimes called alligator grass (*Alternanthera philoxoides*) (Mart.) or (*Achyranthes philoxeroides*) is a member of the Amaranth family closely related to pigweed. It is commonly found in ponds, ditches, bays, and sluggish streams where it forms floating mats over extensive areas crowding out other plants. Alligator weed is a native of Central and South America and according to Penfound it was discovered in the New Orleans area in 1898 by R. S. Cocks.

The plant usually becomes established in wet soil near the water's edge and then extends downward and out over the water by means of horizontal floating stems. Flowers are produced on vertical shoots growing from the prostrate stems. Since viable seed is not normally produced vegetative propagation is the principal means of spread. The roots when in water do not penetrate the soil, but do grow into the soil when washed ashore or otherwise grounded. If stems are broken mechanically, pieces as small as a single node can produce shoots and roots, thus establishing a new plant.

Distribution: Alligator weed is locally abundant in the lakes, bay and sluggish streams around Jacksonville and has been observed as far south in Florida as Ocala by the speaker. Localized infestations in the vicinity of Miami have been recently reported. This pest is also known to occur extensively in Louisiana, and to some extent in South Carolina, Georgia, Mississippi, Alabama, and Texas. The rapid spread indicates more effective methods of dispersal than the simple matter of vegetative reproductive segments drifting downstream. Lynch reports that alligator weed has already destroyed a vast acreage of valuable waterfowl and muskrat marshes, and is now threatening the salt-water fisheries of inner coastal waters of Louisiana.

He considers this plant a more serious threat to wildlife and fisheries than water hyacinth because it thrives on dry land and in fresh and brackish marches. Russell reports that where water hyacinth and alligator weed compete for dominance in shoal water, the latter is capable of excluding the former. When growing in association they form floating mats, the stage preparatory to development of flotant (floating marsh). In the half century since the introduction of these two species the flotant has developed at a revolutionary rate in Louisiana with the result that greater changes have occurred in the marshland than in the twenty centuries preceding, according to some authorities, and a large part of open waters have disappeared. The implications here are unmistakable.

—Agronomist, Bur. Plant Industry, Soils and Agricultural Engineering, U. S. Dept. Agriculture, Beltsville, Md.

Control measures: Enough experimental work has been done with alligator weed to make it clear that control measures suitable for use against this plant in its terrestial habitat are not equally effective against it in its aquatic habitat. Arceneaux, et al, compared the effectiveness of flaming, hoeing, and 2,4-D in controlling this weed in sugar cane fields in Louisiana. The most

Figure 1.—Alligator weed, *Alternanthera philoxoides* (Mart.), one of our worst water weeds that usually makes its start on wet land adjacent, has been a common pest in Louisiana for many years. Its invasion of upper Florida waters is the proper concern of the present discussion. Note blossoms and free rooting at nodes of stems.

effective method was found to be 2, 4-D. Yields of cane were increased by 5 tons per acre in this case. The sprouts which regenerated following 2, 4-D were spindly and lacking in vigor. These plants were effectively suppressed by crop competition. No measurable effects on the cane resulted from 3 repeated sprayings with 2, 4-D aggregating $4\frac{1}{2}$ lb. of acid equivalent per acre. This is approximately twice the amount needed for satisfactory weed control. Complete eradication or even major decimation cannot, as a rule, be expected from a single application. From repeated spraying at appropriate intervals, progressive destruction of the underground system may be expected. From 3 to 5 weeks should elapse between applications of spray. High temperature and high level of vegetative activity are factors which tend to intensify the effect of 2, 4-D.

Applications of 2, 4-D to alligator weed growing in water will kill all emergent growth but regeneration occurs from the submerged stems with monotonous regularity within two weeks after treatment. Four applications of a dilute 2, 4-D spray made at 3 to 7 week intervals during the growing season greatly reduced the reserve food supply of the plant as judged by the vigor of recovering plants. It has not been determined how long such a treatment would have to be continued to bring about eventual eradication. In the absence of water level control, eradication of alligator weed with present herbicides will be difficult and expensive. Nevertheless, consideration should be given to a chemical measure in an effort to confine localized infestations in view of the potential serious threat which this plant presents.

Less is known about mechanical control measures but it has been reported from Louisiana that crusher boats used for hyacinth removal have been successfully used for removal of alligator weed. Effective removal of this plant by the use of the "saw-boat" or hyacinth cutter is not very promising because of the numerous reproductive fragments which would result from sectioning the stems. There is, in fact, reason to believe that the continued use of saw boats on alligator weed will be a material aid to the spread of the plant.

In the absence of more effective control measures alligator weed is a serious menace to the agricultural economy of southern Florida. The problem will be somewhat simplified by early recognition and treatment of localized infestations.

THE EFFECT OF AQUATIC WEEDS ON FLOW IN EVERGLADES CANALS*

DEAN B. BOGART[1,2]

DEAN B. BOGART

The major canals of the Everglades were designed carefully according to the knowledge and data available at the time and their construction represents a sizable capital investment. It is an unhappy but undeniable fact that the benefit of this capital investment has been only partly realized for long periods of time because of the effect of aquatic weeds on the efficiency of the canals. Thus the care of the designers was nullified in considerable measure by their inability to allow for a factor that developed later. In fact, they could not allow for the factor because it has no dimensions in the ordinary sense and the defect of omission cannot be held against them. The problem was more one of maintenance.

There are many aquatic weeds, and many weeds that tolerate much moisture, but those discussed here are the common ones known as water hyacinth, coon-tail moss, nigger-wool, and Para grass. Many other aquatic weeds exist in the Everglades but it will take someone like Mr. Erdman West to identify and name them for you, which he has done on pages 15-20 of this volume.

HYACINTH JAMS

The water hyacinth has been the most widespread weed in

—This paper was to have been presented by both Mr. B. S. Clayton and the writer. Shortly before the 9th Annual Meeting of the Soil Science Society of Florida, Mr. Clayton, Drainage Engineer for U. S. Soil Conservation Service at Belle Glade, Florida, was assigned to special duty in Washington, D. C., and could not attend the meeting. He organized the joint investigation of friction effect of hyacinth cover on canals by the U.S. Geological Survey and the U. S. Soil Conservation Service. With Mr. Edward King, he performed part of the field work on the slope-area reach of North New River Canal and all of the field work on Cross Canal. The computations of the friction coefficients were made by Mr. Clayton.

—Hydraulic Engineer in charge of surface-water investigations in Southeastern Florida, U.S. Geological Survey, Miami. Transferred to Albany, N. Y., in June 1949. Published with the approval of the Director of the U.S. Geological Survey.

the canals. This prolific plant, with its remarkably beautiful flower, has been the cause of much grief, and many thousands of dollars have been spent on trying to control it or even to just get by with the problems it presents.

You will notice that I have used the form "has been" several times in the previous paragraph, as though the hyacinth problem were a thing of the past. It has not been eliminated as yet, but JOHNSON[1] has shown that it can be controlled in the Everglades. This simple statement, however, belies the magnitude of the work that made it possible to see the water surface of the canals again.

Probably the most obvious effects of the hyacinth on canals are the jams that occur at bridges and water-control structures. Hyacinths, either singly or in groups, often move with the current or are propelled by the wind and lodge very easily on any obstruction they may encounter. Despite their apparently frail structure, these succulent plants can make a surprisingly firm mass that requires considerable effort and ingenuity to remove. The stability of hyacinth jams is such that men can walk on them without fear of breaking through, as shown in Figures 1 and 2. When a jam has begun to accumulate on an obstruction, the current forces arriving plants against the edge of the jam and rolls some of them underneath the jam where the stems, leaves, and roots interlace and, in effect weave a solid mass. The development of a hyacinth jam then is a combination of accretion in area and a rolling-under action that increases the vertical dimensions of the mass.

Where the jam may have a semi-detached status, buoyancy of the plants may cause the mass to build up as much as 10 feet above the surface of the water, as in Figure 1. If such a jam is loose enough, the pile of plants may resemble a volcano, with plants rising slowly through the center of the mass and rolling down the slope. Some of the plants may even be rolled under again, thus establishing a cycle of movement. This kind of jam does not occur very often.

The more-common type of hyacinth jam is shown in Figure 2. Here the plants accumulated on bridge piers, but, instead of building up, the jam built down and horizontally. Thus a mass of plants about 6 feet deep developed out from the piers and ultimately extended from bank to bank of the canal. The jam was laboriously cut into rafts of weed by using 6-foot timber or ice saws. It is expensive to remove such jams and in the aggregate they have cost the Everglades area many thousands of dollars directly, not to mention the less obvious costs of lost canal efficiency. Dynamite has been used to break up some jams, but this herioc measure is seldom employed.

A unique block occurred in the West Palm Beach Canal in which hyacinths jammed both high and deep. In this case it was necessary to hack trenches about 4 feet to the water surface and then cut below that with the 6-foot saws.

Figure 1.—Mass of hyacinths caught on shoal just below control and lock in West Palm Beach Canal at U. S. Highway 1; action of fast-moving water piled the growth more than 10 feet higher than the water surface.

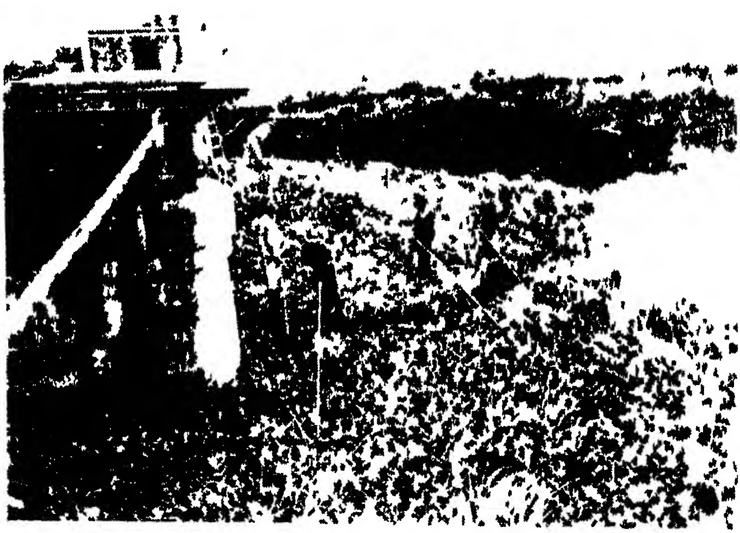

Figure 2.—Jam at F.E.C. Railway bridge at West Palm Beach, Florida. Workers have cut large section loose with 6-foot timber saws and are starting to move it through bridge. When jam moves freely, workers run for ladder which is lashed to the farther pier.

The building of bridges with a number of short spans caused many hyacinth jams to form in the narrow channel openings of the bridges. This resulted in the establishment of a set of regulations |EVERGLADES DRAINAGE DISTRICT,'| that require a principal clear span of 29 feet in any bridge across a major canal.

Little research has been done on the blocking effect on canals caused by hyacinth jams, but as much as a 2-foot backwater effect has been observed at controls in the Everglades canals. It has been reported that flow in lateral canals can be stopped entirely by hyacinth jams.

The Equations of Flow

The flow of water in any channel (or conduit) is expressed by the basic equation:

$$Q = av \qquad (1)$$

where Q = the rate of flow, in terms based upon the unit in which a and v are expressed; it is usually in cubic feet per second (c.f.s.).

a = the area of the channel, in cross-section.

v = the mean velocity of the water in the section.

As a can be measured or designed quite easily, the equation appears simple, as indeed it is for certain purposes. The factor v can be measured in existing channels, but when it comes to computing v, complications arise. The velocity of flow in an open channel can be expressed in the fairly simple equation known as the Manning formula, which probably is the most used of flow equations:

$$v = \frac{1.486\ r^{2/3}\ s^{1/2}}{n} \qquad (2)$$

The Manning formula is combined with equation (1) to arrange all the factors of flow in one question when the volume of flow is the answer sought:

$$Q = \frac{1.486\ ar^{2/3}\ s^{1/2}}{n} \qquad (3)$$

The volume of flow in an open channel, then, can be expressed by four interdependent variables which are used in all of the best known equations:

1. Area (a).—Discharge of a channel obviously varies directly with the cross-sectional area—the larger the channel, the greater the discharge, and so on.
2. Hydraulic Radius (r).—Although the discharge of a channel varies directly with the area, the proportions of the channel have an effect on the volume of discharge. For channels with

—Backwater effect is a measure of the rise in the level of a canal or stream caused by an obstruction; it resembles the reaction of a waterway to a submerged dam.

a cross-sectional area, say, of 1,000 square feet, it is obvious that a channel 100 feet wide and 10 feet deep is more efficient (from several viewpoints) than a channel 500 feet wide and 2 feet deep. The contact of moving water with the sides and bottom of a channel causes a certain amount of turbulence and friction loss; and the greater the area of contact, the greater will be the friction loss. This feature of the proportions of a channel is taken care of by a factor known as the hydraulic radius, which is the ratio of the cross-sectional area of the channel to the wetted perimeter of the channel. The wetted perimeter is that portion of the perimeter of the cross section where the water and the ground material are in contact. As shown in equation (3) the discharge varies as the two-thirds power of the hydraulic radius.

3. Slope (s).—The slope of the water surface of a channel also affects the discharge—the steeper the slope, the greater the discharge, and conversely. The slope is measured in a vertical plane parallel with the current. The discharge of a channel varies as the square root of the slope, rather than directly with the slope.

4. Friction Factor (n).— The flow of water in a channel is a function of the quality of the surfaces of that channel; that is, the relative smoothness or roughness of the channel. A smooth concrete flume surely will carry more water than a brushy or stony channel of the same dimensions. This problem is met by the inclusion of a coefficient of roughness, or friction factor, which appears in the denominator of the Manning formula. By the mathematics of the equation the greater the value of n, the less will be the amount of discharge, other factors being the same. Therefore, the value of n increases with the roughness and turbulence-producing features of channels.

The assigning of a value of n for an existing or a proposed channel is one of the more difficult problems of hydraulics. It is an empirical factor, evaluation of which has been obtained from numerous measurements of flow covering a wide range of channel conditions. Because the value of n has a fairly narrow range for ordinary channels, a difference of a few points in selecting the value means a sizable difference in the discharge being computed. Typical values of n that were assembled by HORTON[2] are listed in Table 1. These values are not fixed, but the tabulation is highly useful as a reference base for general design and computation purposes. The selection of a proper value of n is one of those things that are a matter of experience.

Another part of the friction loss in open-channel flow is that caused by contact of the air with the surface water. This friction loss is definite but for most purposes it is so small that no attempt is made to evaluate it. The easiest way to appreciate that air-water friction is real is to observe the develop-

TABLE 1.—VALUES OF n FOR USE IN THE KUTTER AND MANNING FORMULAS; PREPARED BY R. E. HORTON.[1]

Channel characteristics	Best	Good	Fair	Bad
Canals and Ditches:				
Earth, straight and uniform	0.017	0.020	0.0225	0.025
Rock cuts, smooth and uniform	.025	.030	.033	.035
Rock cuts, jagged and irregular	.035	.040	.045	
Winding sluggish canals	.0225	.025	.0275	.030
Dredged earth channels	.025	.0275	.030	.033
Canals with rough stony beds, weeds on earth banks	.025	.030	.035	.040
Earth bottom, rubble sides	.028	.030	.033	.035
Natural Stream Channels:				
(1) Clean, straight bank, full stage, no rifts or deep pools	.025	.0275	.030	.033
(2) Same as (1), but some weeds and stones	.030	.033	.035	.040
(3) Winding, some pools and shoals, clean	.033	.035	.040	.045
(4) Same as (3), lower stages, more ineffective slope and sections	.040	.045	.050	.055
(5) Same as (3), some weeds and stones	.035	.040	.045	.050
(6) Same as (4), stony sections	.045	.050	.055	.060
(7) Sluggish river reaches, rather weedy or with deep pools	.050	.060	.070	.080
(8) Very weedy reaches	.075	.100	.125	.150

ment of wave action and to consider the magnitude of the forces involved.

The discharge of a channel is expressed by equations other than the Manning formula. The oldest of these, and an apparently simple one, is the Chezy formula:

$$v = C\sqrt{rs} \qquad (4)$$

The terms r and s are the same as described in the preceding section. The term c corresponds in part to the n in the Manning formula but is of a different magnitude.

The selection of c in the Chezy formula was made more positive by the development of the Kutter formula:

$$c = \frac{41.65 + \frac{0.00281}{s} + \frac{1.811}{n}}{1 + \frac{n}{\sqrt{r}}\left(41.65 + \frac{0.00281}{s}\right)} \qquad (5)$$

You will note the Kutter formula incorporates the same factors that were used in the other equations noted in this paper. It is a somewhat cumbersome equation which gives a roughness coefficient (c) by introducing a second roughness coefficient (n).

The Manning formula originally was developed also to provide the value of c in the Chezy formula, but because of its con-

venience it is usually written in the form of equation (3). Both the Kutter and the Manning formulas give comparable results if the person who selects the values of n is accustomed to working both formulas. Most investigators, however, work with one or the other of the formulas, and, owing to its simplicity, the Manning formula probaly is the most used.

Weed Effect On Discharge

The several equations noted in the preceding section are arranged for computing v or Q. In this paper, the equations have been used to compute c and n, which are measures of the roughness and the efficiency of channels. Although values of c are tabulated, the principal discussions are concerned with the value of n, as used in the Manning formula.

As n is a direct mathematical factor in the equation of flow, the ratio of two values of n can be considered a measure of efficiency:

for a clean channel, $n = .032$
for same channel, weedy $n = .060$
efficiency of channel $= \frac{.032 \times 100}{.060} = 53$ per cent

This is, for the same hydraulic radius and the same slope, the water-carrying capacity of the channel was reduced to 53 per cent by the weed condition (hypothetical).

In an ordinary channel, the water surface of which is clear, the flow of water near the banks and bottom is subject to turbulence, in degree according to the roughness of the banks and bottom. The amount of turbulence varies not only with the roughness, but for a given roughness, varies also with the velocity. As velocities approach zero, the turbulence will be very small and relatively unimportant. With water flowing at high velocities, the turbulence may be very large, and the friction loss, therefore, may be considerable.

The principal part of the water hyacinth is above the surface of the water, owing to the buoyancy of the plant. The fern-like roots, however, extend as much as twelve to eighteen inches beneath the surface of the water, as shown in Figure 7. When a canal is completely covered with hyacinths, thousands of roots hanging beneath the plants may occupy the canal to an average depth of say 1 foot. This is a reduction of the cross section of the canal, and in a canal 10 feet deep would cause a reduction in area of 10 per cent, which is demonstrated by the position of a in the Manning formula, equation (3). A lateral canal only 5 feet deep would have a reduction in area of 20 per cent and an indicated reduction in efficiency to 80 per cent. Thus, it can be seen that the simple reduction in channel area may be a very important factor in the efficiency of canals, a factor that increases in importance as the size of the canal decreases.

The reduction of cross-sectional area is not the principal problem caused by hyacinth cover in a canal. The roots of hyacinths, tender and fragile though they may be, have an effect that is the same as that caused by rough sides and bottoms of canals. The roots cause a surprisingly large amount of friction loss by inducing turbulence in the water. With complete hyacinth cover, a canal becomes in effect a closed conduit and there is no free water surface—see Figures 3 and 7. Although the mat of plants

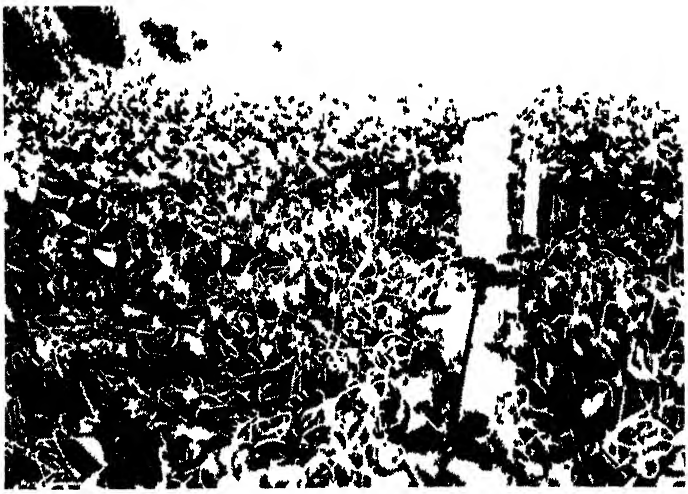

Figure 3.—Complete cover of mature hyacinth on North New River Canal at South Bay, Florida. View is downstream along centerline of canal. Wilted plants in foreground were sprayed with 2, 4-D two days before photograph was taken.

can rise and fall with changes in water level, it continues to restrict flow, whatever the depth of water.

On a large canal the reduction of efficiency is as great as 50 per cent. This means that unless the canal is maintained clear of hyacinths, about one-half of the capital investment of the canal is not realized. Consider the state of the canals in the Everglades for a period of years prior to 1947, and you will realize what a lot of money was wasted because of the inability to cope with the hyacinth problem.

Hyacinths are not the only aquatic weed that reduces the flow in the Everglades canals—see the line-up of obnoxious weeds on page 23 in this volume. The term "nigger-wool" (a *naiad?*) is used in the Everglades to designate a wide variety of bottom-rooted weeds, the scientific names of which the writer does not know and, therefore, nigger-wool will be used here for the sake of simplicity. These bottom-rooted weeds usually exist only in the absence of hyacinths. Apparently they need the sunshine that a hyacinth cover intercepts. They are wonderful plants which in their way are just as prolific as hyacinths, attaining

lengths as great as 25 feet and rising in graceful arcs to the surface of the water. In mass they constitute a very effective barrier to flow, such that a major canal might have an indicated efficiency of only 10 per cent. These bottom-rooted weeds, therefore, can outdo hyacinths as a pest. Some extreme examples of this condition are shown in Figures 5 and 6.

Nigger-wool also forms serious jams at bridges and control

Figure 4—A sizable canal in period of extreme drought, with a variety of aquatic weeds and water-tolerant weeds essentially blocking all flow. View is to south along Kromc Avenue Canal from the Tamiami Trail, at a point 17 miles west of Miami

structures. In rainy periods as the water in a weedy canal rises, a certain amount of flow occurs which gradually overcomes the weed by making it lie flatter and depressing it toward the bottom of the canal. Flow then occurs only in the upper part of the cross section, and as the velocity of flow increases, the plants tend to break up and move downstream. It is probable that the roots remain in place, however, unless the bottom of the canal scours in considerable degree, and the stage is thus set for a regrowth of the plants. Experience in the field indicates the possibility that plants of this nature tend to break up not only from the action of moving water but also from the reduction of air temperature in the fall of the year. The writer does not know if any research has been done along these lines, and points out the difficulty involved in such research because the higher velocities in the canals often occur at the time when the weather becomes cooler.

When nigger-wool breaks up, whatever the cause, it moves downstream and often collects in large masses. These collections become as large as 20 feet in diameter, and, because the plants have nearly the same density as water, the masses may be sev-

eral feet thick Under certain conditions, apparently when the plants have lost their small amount of buoyancy, clumps of weeds are submerged and move downstream with none showing at the surface.

Like hyacinths, the detached nigger-wool forms jams at bridges and water control structures While the jams ordinarily are not as extensive as the larger hyacinth jams, they may cause

Figure 5—Efficiency of canal reduced to about 10 percent by long streamers of weed; view east along Tamiami Canal near Miami city limits

just as much restriction to flow. The plants are soft but tend to pack hard against obstructions and have to be cut away with long-handled choppers.

The possibilities of damage from weed jams are well demonstrated in a report by JOHNSON,'. Aquatic weeds started breaking loose in one of the larger canals of Lake Worth Drainage District. A mass of the growth accumulated and continued to increase in size by a rolling action similar to that of a snowball. The large mass of weeds lodged on an obstruction (apparently a bridge or water control) and completely clogged the canal. As head developed on the plug thus formed, water by-passed the plug and a washout developed. This continued until the washout was about half the size of the canal section and head loss at the constriction was reduced to a negligible amount. The event occurred in a region of deep sand, but a similar washout could occur in areas of other soils.

In drought periods, a variety of water-tolerant plants tend to establish themselves in shallow canals, as shown in Plate 2-B. Most of these plants do not thrive in deep water but for long periods they can make the efficiency of a canal very low and even stop flow altogether.

Not shown in any of the illustrations of this paper, but appearing on page 17 of the paper by West is Para grass. This luxuriant plant is what Mr. West calls a *banker*. It roots on the banks of a canal but tends to grow out through and on the water and may cause a serious reduction in canal capacity. This pest (as far as canals are concerned) has caused trouble in ditches and laterals for many years, but only recently has it affected the

Figure 6.—A major canal in which discharge capacity is greatly reduced by heavy growth of bottom rooted weeds; view of Miami Canal at Pennsuco. The small amount of hyacinths shown is a rarity in the lower Miami Canal and is the most seen in 7 years of intensive inspection along the canal.

larger canals. In the spring of 1949, Para grass had encroached on Hillsboro Canal at Belle Glade from both banks (As shown in the photo cited above) and the visible surface of this 70-foot wide canal was reduced to a narrow lane about 20 feet across. Just what was occurring beneath the surface was not determined, but it is likely that the efficiency of the canal was less than 50 per cent.

Other crawling bankers tend to move out on and through hyacinth cover on a canal, and, by weaving themselves through the hyacinth plants, help develop a mat of weed that is extremely hard to break up. The writer has seen this condition at numerous locations in the Everglades but the outstanding example of this sort was where pigweed 10 feet high was growing on top of the hyacinth and intertwined bankers. One other example of extreme weed condition comes to mind, when some enterprising citizen had beaten the weed growth down to a flat surface, where mixed with muck, it had formed what was practically a soil. There, on top of about 8 feet of water, this person had planted a

seed bed and garden. Needless to say, a jam of this stability is very hard to destroy.

North New River Canal

In 1942, Mr. B. S. Clayton laid out a half-mile slope course on North New River Canal at the Palm Beach-Broward county line. At that time there was only a narrow fringe of hyacinth plants along the banks of the canal and there was evidence that, without any maintenance, the canal would be covered with hyacinths within a year or two. Discharge was measured with a variety of water conditions by engineers of the U. S. Geological Survey and the water slope was measured at the time of each discharge measurement. Additional observations were made as the fringe of hyacinths increased and ultimately the surface became entirely covered, making it necessary to hack an opening across the canal in order to make the observations. One of the difficulties in doing this kind of work in the Everglades is the flat water slope usually encountered. Despite this limitation, the computations show a gratifying degree of consistency.

Some of the basic data from the discharge measurements and the roughness coefficients computed from the data are shown in table 2. Coefficients were computed using all three of the principal discharge formulas—Chezy, Kutter, and Manning. It will be noted that the values of n increased as the amount of hyacinth cover increased, to a point where the efficiency of the canal was only about 40 per cent of the efficiency when the surface was free of hyacinths. Although values of n often are used interchangeably in the Kutter and Manning formulas, the results of these observations show a significant difference between the values of n computed by the two formulas using the same base data.

Referring to Table 2, the $n = 0.022$ (Manning) for the observations on May 22, 1942, shows that the reach selected for the study was in surprisingly good condition. The writer believes that $n = 0.030$ or $n = 0.035$ is generally used for designing large canals in the Everglades. It is interesting to note the increase in the value of n as the fringe of hyacinth developed along the banks. The $n=0.033$ on June 13, 1942, may be larger because of the increase in velocity, but it is believed that most of the increase can be attributed to the encroaching hyacinth mat. The observations made in 1943 and 1944, when North New River Canal was completely covered with hyacinths, show the notable increase that occurred in the roughness coefficient. The value of n ranged between 0.048 and 0.069 and a fair average would be 0.055, although this would in part depend upon the depth and velocity of the water. Thus, n increased 2.5 times, and the reciprocal of this change, 0.40, or 40 per cent, is a measure of the water-carrying capacity of the canal.

TABLE 2.—COMPUTATION OF ROUGHNESS COEFFICIENTS FOR SLOPE COURSE ON NEW RIVER CANAL IN THE FLORIDA EVERGLADES

Date	Average maximum depth feet	Average width feet	Discharge c.f.s.	Average cross-section sq. ft.	Mean velocity ft./sec.	Mean hydraulic radius feet	Slope of water surface ft./ft.	Chezy C	Kutter n	Manning n
1942										
May 22[1]	8.7	66.5	238	435	0.547	6.16	0.000006	90.0	0.026	0.022
June 2[2]	9.5	68.4	344	491	.700	6.70	.000010	85.6	.028	.024
13[3]	14.0	77.8	877	829	1.058	9.33	.000028	65.4	.040	.033
1943		With dense growth of hyacinth from bank to bank								
June 17	9.2	67.9	121	474	.255	6.56	.000006	40.7	.062	.050
Aug. 12	9.8	70.3	208	515	.404	6.86	.000017	37.4	.066	.055
Sept. 30	9.6	69.9	210	500	.420	6.78	.000019	37.0	.067	.055
Nov. 9	11.8	77.8	172	665	.259	7.86	.000007	34.8	.078	.060
1944										
Jan. 17	11.8	77.8	190	618	.308	7.31	.000007	43.0	.061	.048
May 1	9.0	67.0	181	456	.397	6.42	.000029	29.2		.069

[1] Hyacinth and grass extended 2 feet out from both banks.
[2] Hyacinth and grass extended 4 feet out from both banks.
[3] Hyacinth and grass extended 6 feet out from both banks.

TABLE 3.—COMPUTATIONS OF ROUGHNESS COEFFICIENTS FOR SLOPE COURSE ON CROSS CANAL IN THE FLORIDA EVERGLADES

Date	Average maximum depth feet	Average width feet	Discharge c.f.s.	Average cross-section sq. ft.	Mean velocity ft./sec.	Mean hydraulic radius feet	Slope of water surface ft./ft.	Chezy C	Kutter n	Manning n
1940		Narrow fringe of grass and hyacinth at banks								
Apr. 4	11.7	61.2	220	513	0.429	7.52	0.000013	43.5	0.060	0.048
Apr. 26	10.5	59.5	256	444	.577	6.77	.000021	48.5	.050	.042
Aug. 8	11.1	60.0	222	477	.465	7.14	.000015	45.0	.056	.046
1941		With dense growth of hyacinth from bank to bank								
Mar. 28	12.1	62.0	159	539	.295	7.76	.000020	23.6	.118	.089
Apr. 25	11.3	60.5	177	485	.365	7.20	.000027	26.2	.097	.080
May 13	11.8	61.4	148	522	.284	7.60	.000018	24.3	.109	.086
May 15	11.6	61.0	152	506	.300	7.45	.000020	24.6	.106	.086
May 16	11.3	60.5	144	486	.296	7.21	.000021	24.0	.107	.086
Dec. 24	10.6	59.6	177	447	.396	6.80	.000038	24.6	.100	.084
1942										
Jan. 5	10.6	59.6	171	447	.382	6.80	.000038	23.8	.104	.087
Jan. 20	10.6	59.7	166	450	.369	6.83	.000038	22.9	.108	.090
Feb. 3	10.1	58.5	128	415	.308	6.46	.000030	22.1	.110	.092

Cross Canal

Another study was made (entirely by Mr. Clayton) on Cross Canal near the Haney and Wedgeworth farms in 1940-42. Cross Canal is smaller than North New River Canal and apparently was not in as good condition as the larger canal. This is shown in table 3 where the value of *n* averaged 0.045, with no hyacinth cover, which is just about twice the value of *n* for North New River Canal when clear and indicates a considerable degree of roughness or unevenness in the sides and bottom of Cross Canal. When the canal was new, *n* probably was somewhat lower.

The second part of table 3 shows conditions in Cross Canal with a dense growth of hyacinths on the surface. The value of *n* ranged from 0.080 to 0.092, and averaged 0.086. This indicates a reduction of efficiency to 52 per cent and again demonstrates in what large degree hyacinth cover can affect a canal. It is unfortunate that the observations were taken when the range of discharge was relatively small. However, recalling the condition of Cross Canal at that time, it is probable that not much more than the maximum flow observed (177 c.f.s.) could have occurred in the canal.

Miami Canal

For some unknown reason, and this itself might make an interesting study, hyacinths were not a problem on lower Miami Canal in the period of observations by the U. S. Geological Survey. As shown in plate 3-B, the only hyacinths ever seen were a few small colonies which did not develop into the complete cover that infested the other major canals of the Everglades. However, from the junction of South New River Canal to the edge of the city of Miami the canal was host to a number of prolific bottom-rooted weeds. The most extensive one of these weeds has been identified to the writer by Mr. West as a *naiad*—see page 23 in this volume. Whatever its identity, the weed found conditions to its liking and usually had an annual period of growth that for long reaches filled Miami Canal from bank to bank and from top to bottom. As shown in Figure 5 it also occurred in Tamiami Canal (in many other canals, too).

This *naiad*, by forcing the water to follow a tortuous path around thousands of stems and leaves, reduced the efficiency of Miami Canal in amazing degree. No specific studies were made to determine the loss of efficiency, but useful information may be gleaned from the stream records maintained on the canal since 1939. Some comparative figures for selected dates are shown in Table 4, which illustrates the weed problem in terms of stage, slope, and discharge rather than from the standpoint of the roughness coefficient.

The data were selected on the basis of a nearly constant drop

(or fall) between the water-stage gages at Pennsuco and at the water plant in Hialeah—in this case ranging between 2.5 and 2.8 feet. As an additional basis for correlation, the stages for the two recording stations also are listed.

TABLE 4.—STAGE, SLOPE, AND DISCHARGE OF MIAMI CANAL ON SELECTED DATES

Date	Mean stage, in feet, m.s.l. datum: Pennsuco	Mean stage, in feet, m.s.l. datum: Water plant, Hialeah	Fall, in feet Pennsuco to Water plant	Discharge in c.f.s. at Water plant
1944				
May 14	3.9	1.4	2.5	500
June 16	3.2	.7	2.5	150
July 2	2.9	.4	2.5	80
Oct. 3	4.4	1.6	2.8	340
Nov. 23	4.4	1.8	2.6	700
1946				
Sept. 8	4.6	2.0	2.6	900

* Mean stage is used because canal was affected by tidal backwater.

The series of five dates in 1944, in Table 4, show nearly a cycle covering the extreme weed situation of that year. On May 14 the flow was 500 sec.-ft. and the reach of canal was infested with weed. By July 2, with the same amount of slope, the discharge had decreased to 80 sec.-ft.—an indicated efficiency of 16 per cent, based on the May 14 data. Discharge increased in the fall of the year and on October 3 was 340 sec.-ft. and on November 23 was 700 sec.-ft., with slope conditions nearly the same on both dates. The increasing discharge shows that the weeds were pretty well beaten down or broken off by the November observation.

If the July 2 and November 23 data are compared, the July 2 condition shows an indicated efficiency of about 11 per cent, which is certainly worse than anything experienced with hyacinth cover in the larger canals. Similar data for September 8, 1946, are included in Table 4 to show that a discharge of 900 sec.-ft. occurred with the same drop between the two observation stations.

Based on these data, it is safe to suggest that efficiency of a canal may be reduced to only 10 per cent when one of the *naiads* and other bottom-rooted weeds take over. In looking at Table 4, the reader may point out that the data are not entirely consistent in that the stages shown for Pennsuco and Hialeah are not the same for the several dates noted even though the amount of drop is essentially the same. This defect is admitted, but it may be argued that the approximately 1.5-foot range of stage in the 1944 series of readings does not nearly account for the variation

in discharge. The problem was one of magnitude and the condition reported does not necessarily represent the worst condition that obtained in 1944.

It may be interesting to note that an attempt was made to cut weed growth of this nature in Miami Canal. In 1944 at the height of the dry season the salt intrusion situation in lower Miami Canal was such that the principal municipal water supply (at Miami Springs) was in serious danger of contamination by salt water that had advanced up Miami Canal to near the well field area. Emergency measures were taken by the city of Miami to protect the water supply and to augment flow of fresh water toward the well field. As part of these measures, the thick weed growth was cut in a 2.5-mile reach of Miami Canal southeast of Pennsuco. A double-edged saw, very narrow and flexible, but 90 ft long, was moved along the canal in a sawing motion and about 50 per cent of the cross-section was freed of weeds. Undoubtedly more water was able to move downstream because of this work, but the over-all success of the project could not be determined because rainfall complicated the observations.

CONCLUSIONS

It has been shown that where a large canal is covered with hyacinths the efficiency of the canal as a water carrier may be reduced to 40 per cent. This means that the capital investment likewise may be only 40 per cent effective and may in part explain the cause of some of the financial difficulties of the Everglades area in the period 1930-45. Thus, more benefit per dollar spent on maintenance can be and has been realized by removing the hyacinth cover on the canals than in any other way possible. Even though the canals never were finished according to the original design, the improvement afforded is worth many times the cost involved. Rarely, in engineering, is it possible to achieve a relative increase in efficiency of any facility from 50 to 100 per cent (based on original conditions) for a maintenance cost say of only part of 1 per cent of the capital investment, JOHNSON.[4]

Up to recently, the difficulties of hyacinth cover and weed growth were appreciated by those who operated the canal system of the Everglades, but even they did not know the real magnitude of the problems involved. In recent years, work similar to that reported here has provided an evaluation of some of these problems and also has provided a sound working basis for improvement. Unfortunately, some of the most pertinent studies have been made secondary to the general water problems of the Everglades, but enough information has been obtained so that definite designing and planning can again be undertaken, this time with a much greater degree of confidence. Any reader who has studied intensively the data in Tables 2 and 3 may have

TABLE 5.—COMPUTATION OF DISCHARGE WITH EQUIVALENT CONDITIONS; NORTH NEW RIVER CANAL IN THE FLORIDA EVERGLADES

Date	Average maximum depth	Average width	Discharge	Average cross-section	Mean velocity	Mean hydraulic radius	Slope of water surface	Chezy C	Kutter n	Manning n
1947	feet	feet	c.f.s.	sq. ft.	ft./sec.	feet	ft./ft.			
July 23[1]	13.40	77.8	1050	788	1.33	9.50	0.000042	66.5	0.038	0.032
No. 1[2]	13.40	77.8	622	788	.789	9.50	.000042	---	---	.055
No. 2[3]	15.40	77.8	840	944	.89	11.36	.000042	---	---	.055
No. 3[4]	17.40	77.8	1080	1099	.984	13.24	.000042	---	---	.055

[1]As measured; no hyacinth cover
[2]Same stage; with hyacinth cover
[3]Stage 2 feet higher; with hyacinth cover
[4]Stage 4 feet higher; with hyacinth cover

wondered why the loss of efficiency in North New River Canal with hyacinth cover was greater than the loss in Cross Canal; particularly, as North New River Canal is the larger and should have been affected less by the cover. Based on his experience on these two canals the writer can give no positive answer, except to point out that Cross Canal has been a very poor carrier

Figure 7.—Portrait of a hyacinth plant and one of its "Offsprings." The small plant at the right is from a stem that has emerged from the crown of the larger plant. This is thought to be its principal means of propagation. Note also the long root mass that is only partly shown that normally is suspended, full length, in the water and is the cause of so much loss of flow in a channel which has its surface covered by such a growth.

of water and apparently contains obstructions or a large measure of roughness that does not occur in North New River Canal. This is shown by the higher value of n for both clear and hyacinth cover conditions in Cross Canal. It also suggests that hyacinth cover was not the only weed condition that reduced flow in Cross Canal.

Mr. Clayton made some further computations which are listed in Table 5. In July 1947, when the great Everglades flood was developing, the writer made a discharge measurement of North New River Canal at the slope reach. The actual observations are noted in Table 5 and from them $n = 0.032$ was computed. The discharge was relatively high and there was no hyacinth cover. As item No. 1, Mr. Clayton has taken the same information and computed the discharge using $n = 0.055$ as obtained when there was hyacinth cover on the canal. This shows a decrease of discharge from 1,050 to 620 sec.-ft., a reduction of about 40 per cent. It was fortunate for the Everglades that the hyacinth cover on the major canals had largely been removed by the time of the great flood. The writer does not mean to imply that the hyacinth mat was a deciding factor in the severity of the flood, but he does believe that the period of flood conditions was sensibly shortened because the hyacinths had been removed.

As items Nos. 2 and 3 in Table 5, Mr. Clayton increased the stage, that is, the depth of the water by two-foot increments and figured the resulting discharge using the same slope of the water surface. These computations show that with the canal covered with hyacinths, it would have been necessary to have four more feet of water to produce the same amount of flow that occurred on July 23, 1947, when the canal was clear. This information has been included in the paper to provide a means of making comparisons between discharge with and without hyacinth cover.

Based on the information presented about the effect of the bottom-rooted weeds on flow, the writer is wondering if hyacinths are the chief pest among the aquatic weeds—and this question is shared by a number of others who work with the canals. It has been observed that where hyacinths do not exist or where they have been removed, the bottom-rooted weeds tend to move in with resultant loss in canal efficiency. Although this may be a slow process in the major canals in the Everglades, now that the hyacinth problem has been brought under control, there is reason to believe that the other weeds will have to be considered. The writer does not suggest that possibly hyacinths should be encouraged to grow again as the least of several evils, but he does recommend that serious attention be given to the possibilities of the situation. By the time this paper is published, it may well be that the means for destroying nigger-wool, the naiads, and Para grass will have been developed. From the progress of the last several years, it seems that this should come about. How-

ever, the tenacity of the naiads and the rapidly increasing growth of Para grass indicate that the weed problems of the Everglades are by no means over.

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THE RELATIONSHIP OF WATER WEEDS TO NAVIGATION

W. TERRY GIBSON*

This most difficult and, at times, vexing problem was discussed by Mr. Gibson with the knowledge and understanding of one who has had a considerable amount of personal contact with it; also with a restraint born of the circumstances attending the Symposium whereas the vocabulary of a tugboat captain doubtless would have afforded a much more direct incision to the subject, all circumstances considered.

Inasmuch as Mr. Gibson did not provide a formal manuscript to cover the subject of his discussion, the general setting of the relationship is well illustrated and, indeed, may be all but sufficiently set forth by Figure 1 which is helpfully offered—a hyacinth eradicating boat that does not seem to be too sure of what is happening or of what is going to happen. Naturally the difficulties occur whether the weeds involved are what Mr. West has so aptly classified as "Floaters," "Bankers" or "Sinkers" or mixtures thereof.

In any event, Mr. Gibson pointed out that it required no great feat of the imagination to picture the heroic struggles Everglades pioneers must have been subjected to in fighting their way through such obstacles when the waterways were the principal avenues of ingress and egress to the lake region whether for moving ordinary supplies, heavy equipment such as draglines and large barges or merely themselves.

While Mr. Gibson placed great importance throughout his discussion on the development of water transportation in such an area as South Florida by pointing out that "Boats for pleasure as well as other uses bring revenue to the area" he also emphasized there should be no public fear of over-emphasis of navigation from the Federal standpoint as just another feature of government control such as seems to be entering the minds of some people. He also very strongly urged that more and more attention be given to the coordination of soil and water conservation planning and operations into a strong, carefully integrated system of development in which all elements are known to be so highly compatible if properly developed and understandingly brought together.

—EDITOR.

[1]—Attorney, West Palm Beach and Ranchman, Bean City, Fla.

Figure 1.—An early hyacinth-eradicating appliance operating in the upper reaches of the Miami canal in 1940 rather well illustrates the problem of water-bourne craft in those days; also the impossibility of eradicating this rapidly growing pest be mechanical means of this nature. The upper view of the machine shows it "Going" and the lower one "Coming."

HYACINTH HAZARD TO AMPHIBIOUS AIRCRAFT AND SEAPLANES IN THE STATE OF FLORIDA[1]

WILLIAM C. LAZARUS[1 1]

Florida's 58,666 square miles of area is so interspersed with fresh water lakes, rivers, and protected coastal waters as to make it ideally suited for safe operation of amphibious aircraft and seaplanes. Any lake or body of water 2500 feet in length is a potential seaplane landing area. 1000 feet of water provides a safe emergency landing area for such aircraft when in trouble. Therefore, nearly every body of water in the state is a potential safe landing area for amphibious or float equipped aircraft.

Obstructions such as water hyacinths on the surface of the water are extremely hazardous to the landing of such aircraft. These aircraft in general have relatively high centers of gravity necessary for keeping the propellers well away from the water for proper operation. Any amphibious aircraft or float equipped aircraft weighing less than 5,000 would be completely wrecked with probably loss of life if it were to come in contact with a floating mass of hyacinths three feet or more in diameter. Landing on waters completely covered with hyacinths would be certain death to the occupants of the plane as immediately upon contact the plane would be nosed over.

It therefore appears obvious that the safety of flying can be greatly enhanced by the eradication of haycinths from the waters of lakes and canals in the State of Florida.

The following specific examples are cited to support this claim:

A Luscombe airplane being flown from Miami, Florida to the West Coast of Florida was following the Tamiami Trail across the Everglades. It's altitude was 500 feet when it encountered engine failure. The canal along this highway was fortunately free of hyacinths at this point and the airplane being equipped with floats was able to land safely in the canal. If hyacinths had been present at this point it is probable that the occupants would have been killed, or at least an aircraft worth approximately $4,000 would have been totally lost.

There are approximately 600 miles of canals in the Everglades area alone similar to the one paralleling the Tamiami Trail. Every foot of these is a potential safe landing area for aircraft. Aircraft equipped with floats or hulls now religiously avoid areas where the waterways are congested with hyacinths. A truly safe direct line flight from Miami to the Tampa area is now impossible for float equipped aircraft because of this hyacinth hazard.

[1]—Presented by O. W. Jordan.

[1 1]—Aviation Supervisor, State Improvement Commission, Tallahassee, Fla.

The entire Kissimmee River Valley would become a natural airway from Central to South Florida for amphibious aircraft if the hyacinth hazard was eliminated. Hundreds of lakes and other fresh water areas, would be potential landing areas if the hyacinths could be removed.

I estimate that with proper hyacinth control and eradication in Florida, we would open up at least 3,000 safe landing areas for seaplanes and amphibians. We have the natural water landing area. All we need to do is to clear them and flying safety will be increased many times.

The benefits of this program would be to the United States at large and not only to Floridians. Annually thousands of personal airplanes fly to this state from all over the country. It therefore becomes a national problem and should be considered as such.

Seaplane and amphibious flying is not highly developed in this state or other states at this time, largely due to lack of suitable facilities. Part of this is the lack of suitable landing areas. If a seaplane ramp is built in a lake in which there are floating hyacinths it is highly probable that when the pilot lands his seaplane in the lake that he may not be able to reach the float as the wind may be from such a direction as to have piled the hyacinths around the dock. A night landing in such a lake would also be extremely dangerous if floating hyacinths were encountered in the landing run of the aircraft. Consequently there is little or no night water flying being done due partially to this hazard. If we are to make the airplane really useful it must be capable of safe night operation as well as day operation.

Civil Aeronautics records of aircraft ownership show that as of June 1, 1948 there were 2964 airplanes owned by residents of Florida. Of this number approximately 10% are amphibious or equipped with floats. Florida aircraft dealers expect that at least 1,000 amphibious or float equipped airplanes will be locally owned in this state within the next 5 years. I have personally interviewed these dealers and a great many airplane owners who are looking forward to flying amphibious airplanes in our state. They want the waterways made safe for landing these aircraft.

Another immediate example is at hand where hyacinths are definitely interfering with the use of aircraft. I refer to the use of a seaplane by the U. S. Geological Survey, Ground Water Division in the Kissimmee River Valley for reading the water level gages in that river. These gages are out from shore and can best be reached by use of the seaplane. However, many times the gages are so surrounded by hyacinths that the seaplane cannot get near enough to the gage to read it, even though it is able to land on open water nearby.

There are at present 35 seaplane bases in operation in the

State of Florida. Only nine of these are located on fresh water. Fresh water operation of a seaplane or amphibian is much more desirable from a maintenance standpoint. Salt water is extremely hard on aircraft parts and finishes. Why are so few of our seaplane facilities on fresh water then? One of the answers is water hyacinths. An operator can never be sure his base will be usable if hyacinths are floating in the lake or river. A wind shift can occur and make what might normally be a safe landing area a death trap. We fence all airports to keep cattle and livestock off of them to insure a safe landing area for land planes. What are we going to do for the pilots of seaplanes and amphibians?

THE WATER WEED PROBLEM FROM THE STANDPOINT OF WILDLIFE AND FISHERIES*

JOHN J. LYNCH*[1]

JOHN J. LYNCH

We all realize that the water hyacinth and alligator weed are problems from the standpoint of the wildlife and fisheries of the Gulf Coast, but we may not be fully aware of the enormity of these problems. We know that water weeds interfere with utilization of wildlife and fisheries, but many of us overlook the fact that a considerable segment of our population depends upon these resources for recreation, food, and means of gainful employment. We now know something about the direct effects of water weeds on fresh-water fisheries, but we are just beginning to appreciate their more serious indirect effects. We are slow to recognize the potential impact of water weeds upon the total ecology of these resources.

These weeds have been a bane to sport fishermen and hunters, and the end of their troubles is not yet in sight. Thousands of acres of good fishing and hunting waters are now covered by water weeds. Additional tens of thousands of acres, although not as yet infested, can no longer be reached due to weed-blockage of canals and streams. These waterways are the highways of the wet-lands. A single acre of hyacinths or alligator weed, strategically placed, can exclude fishermen and hunters from vast tracts of marsh and swamp. This same acre of weeds may be dispersed at one time of day, so that the sportsmen can get thru to the waters beyond the block, but a shift in the wind can jam the floating weeds, and confront him with an impenetrable barrier when he returns. At best, his day of restful relaxation will end in a back-breaking struggle to get home. At worst, he may have to spend the night with the mosquitoes.

We can get some idea of the recreational importance of fish

*—Presented by T. C. Erwin.

*[1]—Biologist, Fish and Wild Life Service, U. S. Dept. of the Interior, Abbeville, La.

and wildlife from sales of hunting and fishing licenses. In the 1946-47 season, sportsmen of the five States bordering the Gulf of Mexico purchased 227,743 Federal Duck Stamps. A large proportion of these waterfowl hunters hunt in marshes and lakes that are susceptible to weed encroachment. Florida angling license sales show that at least 75,000 resident anglers fish in fresh waters of this State each year. The famous Florida large-mouth bass contributes to the tourist business of this region, as indicated by annual sales of nearly 20,000 non-resident angling licenses. Louisiana licenses about 25,000 resident and 7,000 non-resident anglers each year. Few of the Southern States require licenses for "cane-pole fishermen," so we have no record of the number of people that fish stream-banks, canals, and roadside ditches. We would venture to guess, however, that a quarter-million men, women and children fish with cane poles, both for the sake of a family outing, and for the more serious purpose of supplementing the family larder.

Our fresh-water fisheries, in addition to their value for recreation, are important commercially. Aquatic weeds are a grave problem to commercial interests. The thousands of fishing and hunting camps in the Gulf States represent a multi-million dollar investment in camps, boats, and other accommodations for the tourist-sportsman. Weeds, particularly the water hyacinth, discourage fishing and hunting, and may completely tie-up boating for weeks at a time. Many camp operators fail to realize a profitable return on their investments due to periodic shut-downs during the tourist fishing season, and some have been forced out of business by the water hyacinth.

The commercial fresh-water fisheries of the Gulf States are big business. In Louisiana, some 5,000 commercial fishermen catch 20 million pounds of fresh-water fish, turtles, crabs and crawfish each year. Florida licenses 1,040 retail and 340 wholesale outlets for fresh-water fisheries products. The combined investment of these commercial interests in boats, gear and shore-installations runs into millions of dollars. Floating mats of weeds are a grave problem to this industry. They block the waterways that lead to fishing grounds, and tear up set-lines, nets, traps and other fishing gear. Even the salt-water commercial fisheries are affected by weeds since the shrimp and oyster-boats of Louisiana are harbored in tidal bayous that are subject to periodic weed-blocks.

Mats of water hyacinth and alligator weed are known to kill fresh-water fish. They blanket the surface of ponds and streams and reduce the oxygen content of these waters to a point below the safe limits for game and pan-fish. This destruction of fish is serious in itself, but it has an even greater significance to fish populations. Our Southern warm-water fish have tremendous reproductive capacity, and would recover rapidly from periodic disasters, provided that the total fish population, including game-fish and predacious species were killed off in comparable propor-

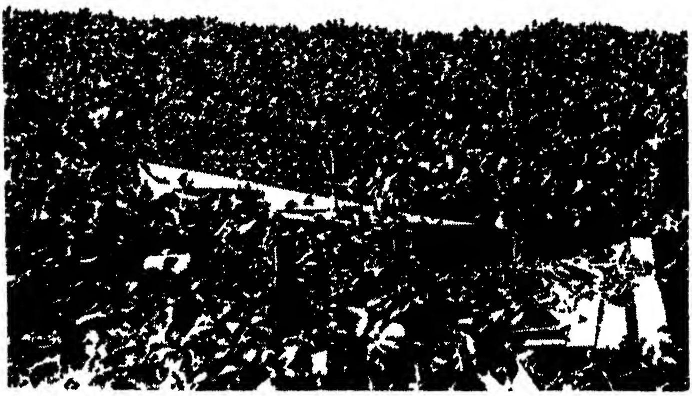


Figure 1.—Wind-driven Hyacinth mats interfere with boating and cause many hunting and fishing camps to suspend operations. (Lake Trafford, Fla.)

Figure 2.—Drifting Hyacinth in Bayou Grand Caillou, Louisiana. Weed jams frequently block this busy waterway, tying up shrimp and oyster boats.

tion. Unfortunately, fish-kills that are associated with weed infestation are highly selective. Game species such as the bass and the better pan-fish are the first to feel the effects of weed-coverage, since they have a higher oxygen demand than coarse fish. The gar, our most serious predatory fish, is immediately benefited, rather than hurt, by floating weeds. Being able to breathe air, the gar frequents openings in the encroaching weed-mats, and game fish that are forced to come to these openings for better-oxygenated water fall easy prey to this voracious predator. This selective kill, coupled with destruction of game-fish spawning grounds by wind-driven weed-mats, upsets lake balance. Many of our fishing waters now have unbalanced populations due to weed encroachment. This is most noticeable in some Florida Lakes such as Lake Trafford, that formerly were excellent bass waters. These lakes now have a super-abundance of pan-fish or predacious fish, but bass are limited to a few extra-large individuals that are virtually impossible to catch. The vigorous younger generations of bass that make for healthy, balanced fishing waters are absent in these lakes, due to destruction of spawn and young by pan-fish and predators.

These many indictments against the water hyacinth and alligator weed, in themselves, would justify most strenuous efforts in weed control. But there is a still graver aspect to the problem. The spread of hyacinths and alligator weed represents an insidious invasion of wildlife and fishery habitats. A gradual alteration of many of these habitats already is apparent, and further unfavorable ecological changes are to be expected.

Our Gulf Coast marshes are most attractive to wildlife in sub-

Figure 3.—Alligator weed in Cameron Parish, Louisiana. This weed not only has closed the canal to navigation, but also is invading adjacent marshlands with every high tide, destroying valuable waterfowl and muskrat habitats.

Figure 4.—Floating mats of alligator weed are impassible in conventional powerboats.

Figure 5.—This abandoned reclamation district in Louisiana (aerial view) was highly productive of fish and waterfowl prior to invasion of water hyacinth. The rapid growth of hyacinth (dark areas on photograph) is now taking over the last open water areas, and floating marsh (the lighter patches on the photograph) that is developing on older hyacinth mats will ruin this lake for all time.

climactic stages. Prolonged freedom from disturbance permits development of edaphic climax. Climax marshes are relatively worthless for wildlife. Nature discourages climax by catastrophic disturbances such as drouth, fire, floods, hurricanes, and animal overpopulations. In our studies of marsh management we have found it possible to duplicate, and in some cases improve upon, the beneficial results of these drastic natural treatments by judicious use of fire, grazing, water manipulation, salt-water intrusion, and mechanical as well as "biological" cultivation. Our fundamental aim in marsh management is the reversal of plant successions to the submerged aquatic and emergent stages, since these are the best wildlife habitats. Unfortunately the introduced water hyacinth has proved to be far more successful in the fresh-water hydrosera than are any of our native submerged or floating-leaved aquatics. Alligator weed has found a most favorable niche in the emergent zones of our fresh and slightly-brackish marshes. Once established in these respective zones, these pest plants totally eliminate the native species that furnished food for waterfowl and fur animals. In effect the hyacinth and alligator weed usurp the place of the more desirable plants in the secondary succession. Hyacinths may completely by-pass the aquatic and emergent stages in our fresh-marsh succession, and precipitate an undesirable climax, since their durable floating mat becomes a substrate that permits immediate invasion of climax species.

Our knowledge of marsh management for wildlife is increasing each year. But any of the management measures now available, and any that are likely to be devised in the future, will be concerned with maintaining plant associations in their lower successional stages. Water hyacinths and alligator weed have demonstrated an amazing capacity for usurping and dominating these stages. Thus the hyacinth may utterly defeat our management efforts in the fresh marshes, and alligator weed capitalizes on our management of the brackish marshes for waterfowl and muskrats by taking them over. To put it bluntly, cultivation of these marshes for wildlife is fast becoming tantamount to cultivating them for the growth of water hyacinths and alligator weed.

We are beginning to revise some of our earlier concepts of the ecology of fishery habitats. Viosca[k] first called our attention to the importance of overflow lands in fishery food-chains of the Mississippi Flood Plain. He pointed out that fish of the swamp lakes and streams derived much of their food from adjacent flood-bottoms, and showed that any diminution in fertility of the overflow lands would be detrimental to these fisheries. We find that a similar situation exists in the fisheries of our coastal marshes. A small marsh pond, only a few acres in extent, may

[k]—Viosca, Percy J. "Flood Control in the Mississippi Valley in its Relation to Louisiana Fisheries." Tech. Paper No. 4, La. Dept. Conservation, 1928.

Figure 6.—Alligator weed moving down a tidal bayou into the brackish marshes. High salinities discourage this weed temporarily, but it recovers rapidly as soon as tide-waters are diluted by rains.

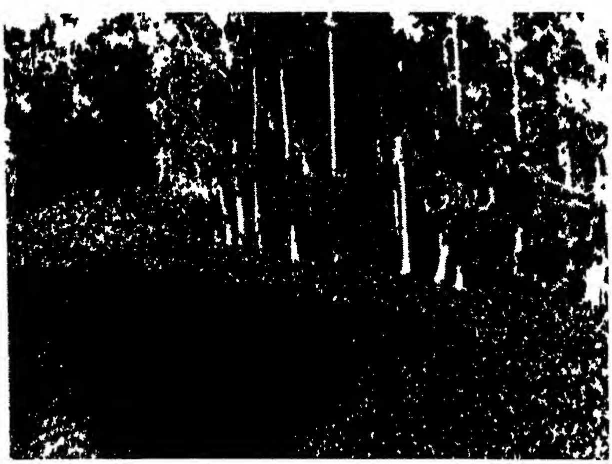


Figure 7.—When water hyacinth invades swamps and backwaters, it may play havoc with vital fishery food-chains. (Bayou Lacassine, Louisiana).

yield an amazing tonnage of fresh-water fish. Such yield, if expressed in terms of production per acre of open water, would stagger the imagination. The situation comes into clear focus, however, when we realize that possibly a thousand acres of the surrounding marshlands have contributed materially to productivity of the pond. In speaking of fishery habitats of the coastal marshes, we, therefore, must take into account not only open waters, but all contiguous backwaters and overflow lands, including those that are flooded only intermittently.

The brackish marshes are important in maintaining our coastal salt-water fisheries. The extent of their contribution remains to be determined, but it is obvious that these marshes must be considered supplementary habitats in the total ecology of the shrimp, oyster, and crab fisheries of our coastal waters.

Water hyacinths already are well-established in the overflow habitats of our fresh-water fisheries, and alligator weed is rapidly taking over the upper tidal habitats of our shore-fisheries in Louisiana. We are not yet in a position to predict the final outcome of this alteration of habitats, but the information at hand is not encouraging. We know that marsh and swamp backwaters are de-oxygenated by weed coverage, and their production of plankton drastically lowered. We have observed that decomposing mats of alligator weed, especially in brackish water, produce quantities of hydrogen sulfide, a gas that is highly toxic to fish and other aquatic organisms. Further investigation of these possibilities is imperative. While awaiting more definite information, we are moved to express grave concern over the invasion of backwaters and overflow lands by hyacinths and alligator weed. We consider these weeds capable of interrupting the vital fishery food chains that originate in these habitats. Pockets of toxic materials generated by decomposing weeds can have disastrous effects when swept into nearby permanent waters by heavy rains.

Our wildlife and fisheries are renewable resources. Many of us interpret the term "renewable" as meaning only that our sporting and commercial harvest of these resources will be compensated for by Nature's bounty. To the ecologist, the term signifies that these resources not only *can* be renewed, but *must* be renewed if they are to be perpetuated. Such renewal is possible only to the extent that the productivity of wildlife and fishery habitats is renewed and maintained. Nature accomplished such renewal in a somewhat hap-hazard manner, and the wildlife and fishery manager seeks to create and maintain these habitats by more orderly means. But water hyacinths and alligator weed have an unhappy faculty for taking over the most valuable niches in our wildlife and fishery environments. In so doing, these weeds can utterly defeat the combined efforts of Nature and man to maintain these environments. Only when we fully awaken to these facts will we begin to appreciate the enormity of the danger that confronts the wildlife and fishery resources of this region.

THE CONTROL OF WATER HYACINTHS BY MECHANICAL MEANS

A. H. BROWN

A. H. BROWN

The plants and the problem they create have been described to you by several able gentlemen. This paper discusses the solution or control of water hyacinths by mechanical means. Mr. Wunderlich[1] has discussed the "Type, adaptability and limitations of mechanical plant under Louisiana conditions," and I shall follow up on the same subject under Florida conditions.

Before proceeding on that subject I want to speak briefly on the existing Federal project which authorizes the operations of the Corps of Engineers for removal of water hyacinths in the State of Florida.

It appears to be the general opinion of those interested in the control of the pest that the Corps of Engineers has the authority and the responsibility to remove the plants wherever they are found and for any purpose. The facts are quite different. The various River and Harbor Acts which authorize the operations provides only for "Removal or destruction of the water hyacinth in the navigable waters of the State of Florida so far as they become an obstruction to commerce."

That of course confines the operations to navigation channels. Funds are made available accordingly and all mechanical plant that has been used to date was designed to operate in the navigation channels where the water depths are such as to provide flotation. It is needless to tell you that the operational area to which we are limited is very small compared to the extensive lake and other non-navigation areas in the state which are infested with the plant.

The River and Harbor Act of 1905, still in effect, also pro-

*—Chief, Operations Division, Corps of Engineers, Jacksonville, Florida, District.

**—Unfortunately Mr. Wunderlich of the New Orleans District Office could not be present and present his paper. Ed.

hibits the use of any chemical spray that may be harmful to cattle or fish.

Now as to the mechnical means we have used. First, the derrick and grapple. When the plants are permitted to grow to maturity during spring and early summer the late summer and fall rains cause flood conditions that drift them into the main channels. There, with the current and wind, the plants are jammed against bridges or in restricted reaches and are rolled into dams several feet in depth. When this condition develops the derrick

Figure 1.—A large derrick boat operating in the north fork of the St. Lucie River, 1939.

and grapple is the only practicable means of removal. The use of the equipment is limited to just such situations. The photographs of Figure 1 and 2 show this equipment in operation.

Next we take up the conveyor. Several types were constructed and used over the period from 1909 to 1941. Conveyors of all types proved to be impractical for general use under Florida conditions. None are in use at the present time. I can best describe them by the photographs of Figures 3 to 6, inclusive.

The 1940 model was quite a machine. Note the wide pick-up conveyor which moved very slowly and was equipped with forks operated from a crank through a link motion to reach out and pull the plants in contact with the conveyor lugs. Aft of the pick-up conveyor is the discharge conveyor set cross deck and mounted in a trunnion at the center to permit either end to be elevated for discharge to either side. We accomplished something on the cross conveyor that the manufacturers of roller chain said could not be done. We operated this conveyor at about 1,000 feet per minute, the idea being to shoot the plants well up on shore. It worked well and the chain never gave any trouble. The problem

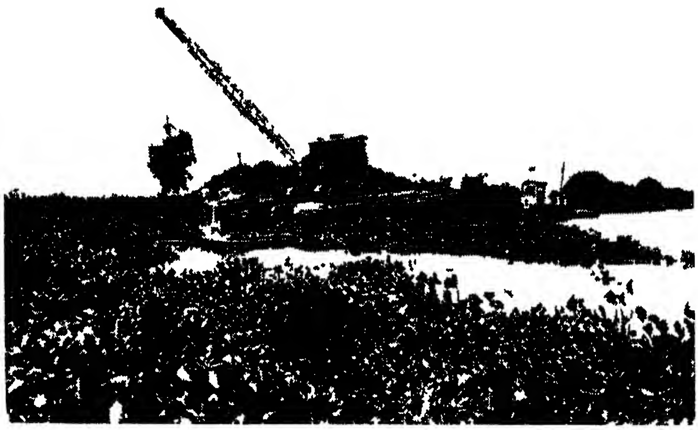


Figure 2.—A dragline operating from a barge to clear one of the navigation channels in Lake Okeechobee, 1927.

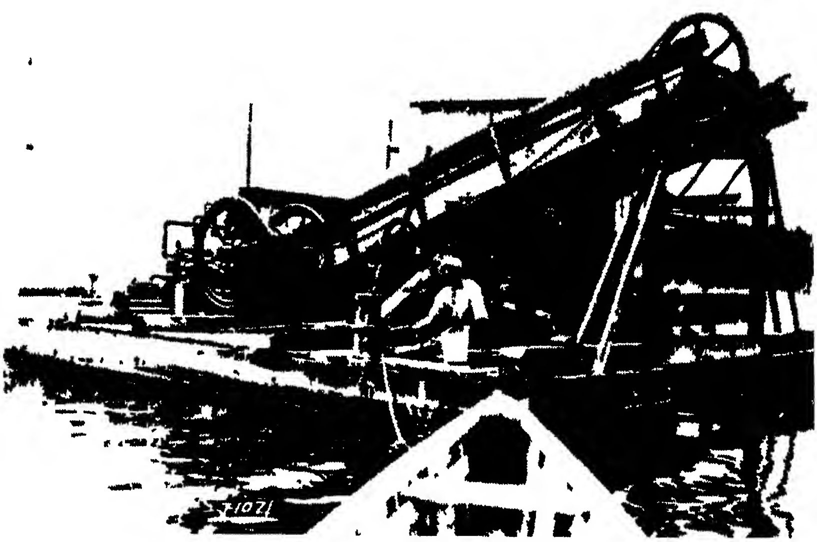


Figure 3.—A 1909 model conveyor used on the St. Johns River.

was to get the plants to and on the pick-up conveyor. Cost of operation was high and output low. The idea was good but these floating hyacinth plants have a way of disappointing you.

I therefore repeat the opinion that elevators are out of the picture as a means of efficient and economical handling of these weeds.

Thirdly, and after we had proved that derricks with a grapple and various types of conveyors were not the answer we found the best mechanical means yet used. Mr. Charles R. Short of Clermont, Fla., a retired Research Engineer, developed the idea. He equipped a small boat with a bank of gin saws which were mounted on a mandrel and set just forward of the boats bow. The saws were actuated by roller chain and sprockets from the propelling engine. After observing the efficient operation of the boat it was purchased by the Corps of Engineers for further tests and study.

From it we developed the present destroyer boats now in use. The destroyer is a boat 17 feet in length with a beam of 6 feet. Three groups of saws are mounted on the boat. The forward group consists of two banks of saws each 3 feet in width actuated independently. The after groups, 1 port and 1 starboard, each 3 feet wide, are mounted on outriggers so as to make a cut 12 feet wide. The saw disks are 12" in diameter with "V" type teeth and turn at about 1,000 rpm. An industrial type power unit of 50 h.p. provides the power which is transmitted to the saw banks through a standard light truck rear axle assembly and thence by roller chains and sprockets. No propelling unit is required. Friction on the rotating saws propel the boat and at the same

Figure 4.—A 1920 model conveyor used on the Withlacoochee River in 1922.

Figure 5.—A machine designed and constructed by the New Orleans, La. District which we obtained in 1939 It is shown clearing the Hillsboro Channel in the Everglades

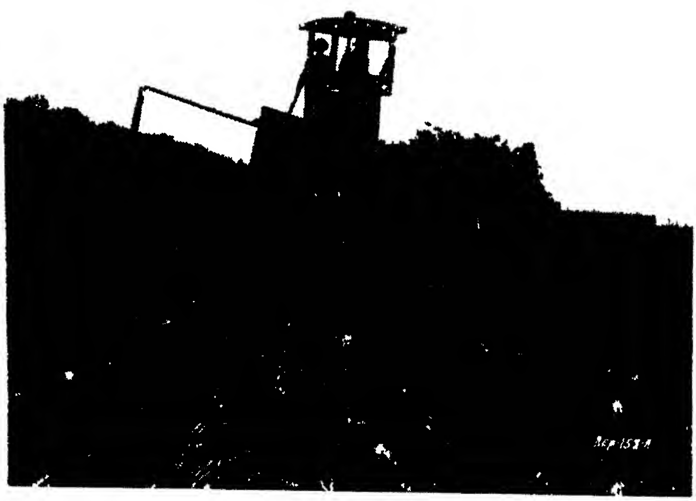


Figure 6.—A 1940 model conveyor (No. 3) working in the St. Johns River near Sanford.

time create a current that draws the floating plants into the saw banks.

The boats are light and are operated usually by two men. The area that can be covered in one 8-hour day varies with the density of the plants; in densely infested areas when plants are up to 45 inches in height 2 to 4 acres per 8 hours and up to 8 to 16 acres in the same time in less dense areas of small plants.

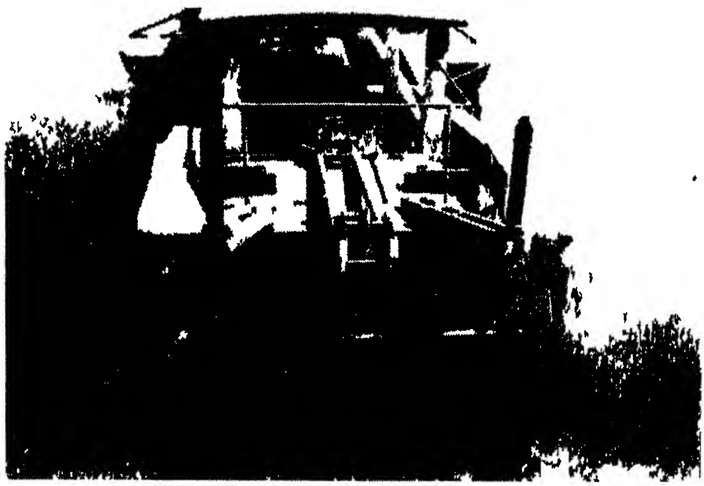


Figure 7.—The hyacinth destroyer—looking at the bow. The blades, rotating at 1000 RPM, propel the boat as well as cut the hyacinths.

Figure 8.—The job. Arbuckle Creek, completely closed, before cutting.

Through the season of operations a boat operating in various locations will cover an average of 8 acres per day at an average field cost of $7.00 per acre. These boats will not operate efficiently in water less than 1.5 ft. in depth.

The saw boats effectively and quickly open channels to navigation and are quickly and easily transported from one location to another. Experience has shown that less than 5% of plants cut by the destroyers will survive. The photographs of Figures

Figure 9.—One cut through the jam with the hyacinth destroyer.

Figure 10.—Further progress has been made with a considerable channel apparent through Arbuckle Creek.

7 to 12, inclusive, will give a better idea of the destroyer and its operation than can be put in words.

These destroyers are adapted to operate in navigable waters and are effective in clearing channels for navigation. You will note on the photographs the rim of plants left on each bank. The destroyers cannot reach them, nor can these destroyers reach many other great areas where the plants propagate and grow.

In closing let me say that we shall never control these pests by mechanical means alone. Nor shall we ever reduce them by

Figure 11.—A close-up of the destroyer in operation

Figure 12.—Channel open with most of debris gone and only fringe growth of hyacinths remaining.

merely keeping channels cut through them. If effective control is to be obtained it will be obtained only by the fullest cooperation of all interests, private, local governmental agencies, state agencies and Federal agencies working on a coordinated plan to destroy the pests at the source, not only for navigation, but for all other purposes.

Any program must utilize both mechanical and chemical means. If the problem is properly attacked and the pests are controlled at their source the only mechanical means then required would be the necessary plant and equipment for practicable and efficient application of the chemical sprays.

MANUFACTURE AND FORMULATION OF 2, 4-D AND 2, 4, 5-T

HOYT A. NATION*

HOYT A. NATION

The purpose of this paper is to explain as briefly as possible the meaning of the term 2, 4-D and to give some understanding of the various formulations of this compound. In order to fully understand the meaning of the term 2, 4-D it is necessary to understand a few relatively simple formulas. No attempt will be made to show exactly how 2, 4-D is made but the different steps in its manufacture will be briefly discussed and a few formulas drawn to clarify our discussion. An understanding of the term 2, 4-D will help to explain other terms like 2, 4, 5-T of which you have heard or will be hearing soon.

2, 4-D is an abbreviation of 2, 4-Dichlorophenoxyacetic acid. Four materials used in the manufacture of this material account for its name.

The first of these materials is benzene which is responsible for the two numbers. Benzene is a product obtained when coal is changed to coke. Organic chemists generally give this material the structural molecular formula shown in Figure 1 and represent this formula by a hexagon as shown in Figure 2. It will be noted from the first figure that a molecule of benzene contains six carbon atoms connected to form a ring by a series of alternate double and single bonds. Each carbon atom has attached to it one hydrogen atom. In chemical reactions it is very difficult to break the bonds between the carbon atoms but very easy to replace any or all of the hydrogen atoms by simply controlling the chemical reaction. It is this feature about benzene that makes it useful not only in the manufacture of 2, 4-D but in many other organic compounds such as DDT and BHC. The chemist uses the hexagon to represent the benzene molecule or benzene ring as it is commonly called because it is much simpler

*—Technical Service and Development, The Dow Chemical Company, Midland, Michigan and Auburn, Alabama.

to construct than the actual formula. When the hexagon is used it is understood that each angle represents one carbon and one hydrogen atom. Because it is possible to replace one or any combination of hydrogen atoms on the benzene ring by certain reactions and because when two hydrogens are replaced on the ring the position of the hydrogen replaced determines to some extent the characteristics of the compound produced (as will be seen later) it is necessary to identify what position in the ring the reacting atoms occupy. For this purpose the angles of the hexagon, or the carbon and hydrogen atoms, are numbered from one to six starting at any point on the hexagon and numbering in a clockwise direction. It is this numbering of the position of the reacting atoms that accounts for the numbers 2 and 4 as will be explained later.

The second part of the name is di which means two.

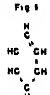
The third part is chloro which indicates the product contains chlorine. When one has an understanding of organic chemistry he can put the above information together and he will know that the material contains two chlorine atoms and that they are on the number 2 and 4 carbons, or angles. Had they been on the 2 and 5 or 2 and 6 position we would have had a product similar to 2, 4-D but differing somewhat in its reaction from that of 2, 4-D.

The fourth part of the name, phenoxy, indicates that phenol or carbolic acid is used in the manufacture and the fifth part, acetic, indicates that acetic acid is also one of the compounds used. Incidentally, vinegar contains acetic acid.

Now that we have explained what the various parts of the name mean, let us take a look at some more formulas to get a better understanding of what actually happens. In the manufacture of 2, 4-D one atom of chlorine is first added to the benzene ring and it is placed on the number one position. This material is a liquid and is called monochlorobenzene. See Figure 3.

Then this material is reacted with sodium hydroxide (NaOH). In this reaction the chlorine is replaced by the OH group and combines with the sodium to form NaCl or common salt. The benzene ring has now become phenol. See Figure 4.

Fig 1



Benzene

Fig 2

The hexagon which represents the benzene ring

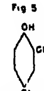
Fig 3

Monochlorobenzene

Fig 4

Phenol

Fig 5



2, 4-dichlorophenol

By heating the phenol and bubbling in chlorine, a chlorine atom is placed on each of the number 2 and 4 carbons. This material is known as 2, 4-dichlorophenol and is shown in Figure 5. These reactions account for the "2, 4-dichlorophenoxy" of our compound name.

We now take acetic acid as shown in Figure 6 and add one chlorine to it as shown in Figure 7. This material is known as chloroacetic acid. By combining chloroacetic acid and 2, 4-dichlorophenol with NaOH, a solution of the sodium salt of 2, 4-D is produced. See Figure 8. The percent 2, 4-D in this solution is low. The sodium salt sold on the market is not the solution produced in this step of manufacture, but is a powder produced by combining the free 2, 4-D acid with caustic soda or sodium carbonate. Pure 2, 4-D is made by treating the sodium salt solution mentioned above with HCl and has the structural formula shown in Figure 9. This is a white crystalline material that is practically insoluble in oil or water. By replacing the H of the OH group of the acetic part of the formula with various materials the different formulations of 2, 4-D are made and these formulations are either soluble in water or in oil as discussed later.

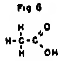
2, 4-D formulations can be separated into two major groups. These groups are salts and esters. A salt is produced by reacting an acid with a base and an ester by reacting an acid with an alcohol.

The salts of 2, 4-D are soluble in water but not in oil whereas the esters are soluble in oil but not in water.

The salts of 2, 4-D can again be divided into two groups; the metallic salts and the amine salts.

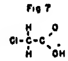
The sodium salt of 2, 4-D is the most common of the metallic group and is prepared by reacting the free acid of 2, 4-D with sodium hydroxide or sodium carbonate. This material is a powder soluble in water and containing a high percentage of 2, 4-D. A study of Figure 8 will show that the sodium atom replaced the hydrogen atom on the OH group of the acetic acid formula.

Fig 6



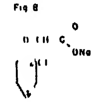
Acetic acid

Fig 7



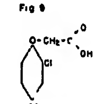
Monochloracetic acid

Fig 8



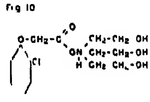
Sodium salt of 2 4 D

Fig 9



2, 4 dichlorophenoxyacetic acid

Fig 10



Triethanolamine salt of 2 4 D

The following discussion is a purely figurative and simplified way to illustrate how 2, 4-D amine salts are formed. The alkanolamine salts can be represented by the triethanolamine salt as shown in Figure 10. These salts are liquids soluble in water and are made by combining *ammonia, alcohol and* 2, 4-*D acid.* In the case of the triethanolamine, three molecules of ethyl alcohol (the kind used for drinking) might be used. This alcohol is known to the chemist as ethanol. Since three molecules are used, this accounts for the triethanol and since ammonia is also used this explains the term triethanolamine salt. The whole group of salts that can be produced by combining the various alcohols with ammonia and 2, 4-D are known as the alkanolamine group

and any salt of that group may be properly called an alkanolamine salt.

Since esters are made by reacting an alcohol and an acid, it is possible to make quite a number of different esters. At least five esters have been or are being produced commercially; they are methyl, ethyl, insopropyl, butyl and amyl. There seems to be no practical difference in the potency or activity of the various metallic salts, the various alkanolamine salts or the various esters, but there are differences in activity among the three groups as a whole. The metallic salts are the least plant toxic, the esters, the most, and the alkanolamine salts somewhere intermediate between the two. The salts are generally considered more safe to use on crops for selective weed control. The esters are often more effective against woody plants and certain herbaceous weeds.

Until recently the alkanolamine salt formulations have been used largely in high volume spraying and so were most of the other formulations. With the advent of low volume spraying, amine and ester formulations have been developed that meet the demands.

I think it fortunate for the Everglades that pioneer work in low volume spraying has been done here. Dr. R. V. Allison, Mr. Charles Seale and Mr. Jack Evans did small plot work and Mr. Lamar Johnson, cooperating with the aviators in this section, has developed methods for large scale hyacinth control. The idea has been carried to field sprayers and low volume application is being used extensively in the spraying of crops.

I believe attention should be called to the fact that the esters on the market at present are volatile to some extent while the salts have little if any volatility. This means that when an ester is used near a susceptible crop like cotton, the crop may show 2, 4-D effect even though it was thoroughly protected from spray drift. This effect is caused from the fumes coming into contact with the crop and the effect can be produced several days after spraying should the wind blow off the sprayed area onto the susceptible crop. For this reason the salts are somewhat safer and should be used, if effective on weeds to be controlled, when susceptible plants are growing in the vicinity of the area to be treated.

In making the various formulations of 2, 4-D the manufacturers have seen fit to vary the percentages of 2, 4-D in their products. It should be remembered that the 2, 4-D (or 2, 4-D acid equivalent) is the significant point of comparison among formulations or products and that one should not expect the same results from a quart of a 10 percent solution as from a quart of a 40 percent product. Therefore, the percent 2, 4-D in a product must be known to allow intelligent comparison of prices and the formulation of correct recommendations for the

use of the material. Each manufacturer shows, or should show, on the label of each of his containers the percent of 2, 4-D (or 2, 4-D acid equivalent) contained in the formulation. Therefore read the label when comparing prices of materials or making use recommendations. Sometimes labels may not state whether the 2, 4-D formulation contains a salt or an ester but this can be determined by pouring a few drops of the material in water. If the water takes on a milky appearance the material is an ester; if no milky color is observed the material is a salt.

Now for a very brief discussion of 2, 4, 5-T. This is the abbreviation for 2, 4, 5-trichlorophenoxyacetic acid. This is the same type material as 2, 4-D but, as the name suggests, it has an extra chlorine atom in the number 5 position on the benzene ring. 2, 4, 5-T is more effective than 2, 4-D on our southern blackberries, osage orange and certain other hard-to-kill plants. An isopropyl ester formulation of 2, 4, 5-T is now being produced in limited quantities and will be available for 1949. For general brush control it has been found that a mixture of an ester of 2, 4-D and an ester of 2, 4, 5-T is very effective.

A REVIEW OF EFFECTIVE GROUND- AND WATER-BORNE EQUIPMENT FOR THE CHEMICAL CONTROL OF WATER PLANTS

JOHN W. RANDOLPH[1]

Many of the herbicidal materials used in the control of water plants have no unusual physical characteristics. That is, most of these chemical compounds can be handled by some form of conventional equipment normally used for overland distribution of dusts or liquids. In the water-borne approach the transportation facilities themselves and the attachments regulating final dispersal of the herbicide are about the only appreciable departures from dust spray or spray units used in land operations.

Undesirable water weeds are frequently so located within natural or artificial waterways that they are virtually isolated insofar as their accessibility through the use of common forms of transportation is concerned. Effective and economical use of any herbicide material depends very largely on the exact dosage applied under a given condition. The desired pattern of dispersal and the rate of delivery per acre of a chemical mixture involve a series of problems that can be worked out best through a preliminary selection of equipment and the adjustment of the required attachments. Unit rate of application of herbicides over water generally is highly variable due to the difficulty of maintaining a uniform rate of travel under water-borne conditions of transportation.

Certain areas of water weeds may be in favorable locations and are accessible to land spray or dust rigs with minor modifications. When such conditions exist, then the lowest cost of weed control can be expected. Under inaccessible conditions, however, the transportation costs of the chemical applicator and the needed crew may represent such a high ratio of total costs that it is often advisable to use a herbicide in excess in order to obtain a maximum effect from the treatment with a minimum movement of the equipment. Water weeds in close proximity to economic plants, whether crop or ornamental, necessitate the use of accurately controlled methods in the application of most herbicides. A good rule to follow where there is any question of danger to the vegetation of adjacent areas is "don't spray."

Water weeds, insofar as the problems of equipment for chemical application are concerned, can be divided into two general classes: (1) exposed or surface weeds and (2) under-water weeds. The herbicides used also can be divided into two general classes: (1) materials that are effective when deposited from the air and (2) materials that must be added to the water with varying degrees of mechanical mixing.

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[1]—Agricultural Engineer, Everglades Experiment Station, Belle Glade.

Herbicide Equipment for Exposed Water Weeds

Hyacinths represent exposed water weeds that can be effectively controlled by surface applications of 2, 4-D or killed back with a contact material. Large open areas of water covered with a dense growth of hyacinths offer a favorable location for the use of the airplane equipped with a low gallonage 2, 4-D spray applicator. Mr. A. E. Holland, a speaker on this program, will explain the advantages of the airplane for use in large, mass killing of hyacinths and also outline for you what water weed locations are inaccessible for the practical use of the airplane and the kinds of herbicides that cannot be properly applied from the airplane.

The Everglades Drainage District used the airplane quite extensively to apply 2, 4-D for killing the long continuous masses of well-exposed hyacinths in the arterial canals of South Florida. The first operation, commonly called the "mass-kill," was very effective except on areas protected by certain forms of barriers which prevented exact applications of the chemical in this manner. Other agencies likewise have obtained excellent results in mass-killing through the use of the airplane 2, 4-D applicator on large, favorably located areas of hyacinths and on follow-up sprays after the hyacinths that escaped the first spray have reassembled.

Old hyacinth growths and areas of high hyacinth compaction, caused by stream flow or wave action, represent conditions virtually impassible for conventional forms of boats. The U.S. Army Engineers and certain South Florida drainage districts have equipped special boats with cutter heads that open up a passage for the boat fitted with a herbicide applicator. The most common form of a cutter head for a "saw boat" is a series of large diameter saws mounted on a mandrel across the bow of the boat. The saw action is to slit the growth and to force it under the boat, the traction of the saws on the hyacinth growth being a means of obtaining forward travel as described earlier in the program by Mr. A. H. Brown.

Many experimental units have been designed to use a single slitting saw and side traction chains to pull a boat through a hyacinth growth. Few references are available to indicate that such designs have received extensive practical use.

Water weeds and other undesirable vegetation produce rank growths on shallow water areas, impassable for most boats. The game hunters of the Florida Everglades have developed a so-called "frog boat," which, in jest, has been considered capable of navigating on a good dew. In actual operation the frog boat can be floated on a few inches of water and can travel over a light growth of sawgrass and other water weeds. This boat is generally powered by a small airplane motor with a conventional

air propeller, and is steered by an air rudder. With no means of reversing the direction of travel, the frog boat will have certain limitations in the application of herbicides in areas with many obstructions.

The Armed Forces developed many forms of landing craft and water vehicles during the past war. Frequently, the dense growth of water weeds and the tractionless value of the soil and sludge under the water growth prevent the use of the military forms of vehicles.

Oil prospecting organizations have developed and constructed several forms of amphibious craft that might be extremely useful in chemical weed control in marsh lands. Conventional four-wheel drive trucks and cars have been modified for use by employing oversize tires and wheels or increasing the underclearance by use of stub axles and chain drives. Figure 1 shows

Figure 1—Marsh Buggy, developed and constructed by Humble Oil and Refining Company.

the "Marsh Buggy" used by Humble Oil & Refining Company. A similar unit, the "Mudhopper," is described in detail in The Oil Weekly, September 23, 1946. The Gulf Refining Corporation have used a "Swamp Buggy" that was equipped with extra large balloon rubber tires that floated the unit in open water.

The Everglades Drainage District has made extensive use of their water truck as shown in Figure 2. This unit furnished the transportation for a high-pressure pump unit that was used to spray 2, 4-D through a brush hand gun as shown in Figure 3. In brief, this water truck consisted of an auto chassis equipped with four large steel cable spools that had been made air-tight by surfacing with plywood and then fitted with 2x4 inch timbers to

Figure 2—Water Truck with spraying equipment designed by Everglades Drainage District, and constructed by Everglades Experiment Station

Figure 3—Spray Brush Gun, a high-pressure nozzle with hand control for variable distance delivery and shut off of liquid

give traction. The wheels, six and one-half feet in diameter, require a relatively slow speed of rotation; hence, it was advantageous to use a six horse power gasoline engine with a 15 to 1 added speed reduction to that contained in the regular transmission and rear axle. While this water truck has certain limitations in maneuverability and it is not free from serious breakdowns, the unit still represents one practical method of transportation for the application of chemicals under very difficult conditions.

Spray Equipment

The cutter head boat, the water truck, saw boat and the other means of transportation into jammed hyacinth growths make it desirable to spray or dust a very large area with the least amount of travel. Air currents can be used to aid the drift of dust applications applied from high velocity dusters if surrounding conditions will permit. Mist distributors, such as the Buffalo Turbin, have been used to cover a wide area with a herbicide by means of a drift. The Everglades Drainage District and other drainage units in Florida have used the basic elements of a high-pressure orchard spray quite extensively for the application of 2, 4-D. The final dispersion of spray has been through a conventional tree or weed hand gun. These spray guns, manually controlled, can be directed as desired to cause the discharge to go some distance before the final breakup or to produce a fine mist distribution in close proximity to the operator. With the selection of available orifices and differences in pressure applied on the spray solution, the final particle size and range of distribution of spray can be varied widely. It should be emphasized, however, that these types of 2, 4-D applicators should not be used near sensitive vegetation.

Hyacinth growths in narrow fringes, scattered groups, and in regular patterns in open water are logical locations for use of low gallonage, concentrated herbicides. The Everglades Experiment Station, in cooperation with the supervisors of local drainage districts, have worked out several forms of low cost applicators for patrol work from boats and land vehicles.

Attention is called to a low gallonage spray unit made for the Everglades Drainage District (see Figure 4). The boat is a light weight skiff made of ply wood and is powered with a standard outboard motor. The distributor consists of a small gas engine and a small gear pump with "V" belt drive. A ball-spring pressure relief valve is so connected in line as to maintain the desired liquid pressure and to by-pass the surplus pumped liquid into the storage tank, thereby keeping a well-mixed solution. A fine mesh screen or filter is used to keep the discharge line free of foreign matter that might clog the small orifices in the nozzles. Clusters of hyacinths along a canal bank were sprayed with 2, 4-D from a light weight "wand" distribu-

Figure 4.—Low gallonage spray unit mounted on boat (Everglades Experiment Station)

tor made by Spraying Systems Company. Variable width borders of hyacinth along the canal bank were sprayed with an outrigger boom equipped with several nozzles, each with a quick-acting shut-off valve. Both forms of spraying were possible at a moderate boat speed. This system represents a low cost patrol program for eliminating the potential regrowth areas.

The small, gasoline engine gear pump unit, through increasing the liquid pressure, was used for operation of a single nozzle brush gun as explained for high-pressure spraying by increasing the liquid pressure.

Records are available on land spray rigs in the west that are equipped with very elaborate outrigger booms for low and high gallonage spraying over irrigation canals. The adaptation of hydraulic controls and use of suitable linkage can make a spray boom quite flexible in respect to location and range of effective action.

Herbicide Equipment for Underwater Weed Control

Most underwater herbicides are effective in definite concentrations, usually expressed in parts per million, and with a given dispersion maintained for a specific time period. These specifications involve the consideration of several hydraulic factors associated with the determination of the quantity of water to be treated and mechanical factors of metering the chemical materials and their dispersion.

Slow flowing streams or water areas subject to artificially controlled rates of flow, offer many advantages through the use

Figure 5.—Fixed station delivery of spray into stream.
(Photo courtesy Cloroben Corporation)

of a chemical applicator at a fixed station as shown in Figure 5. Some herbicides are effective in discoloring the flowing water in a way that is helpful in determining distribution. The initial up-stream point of application may consist of a simple power unit that will deliver the required amounts of materials into the water through any number of spray nozzles of predetermined type. Successive down-stream stations for herbicide application will depend upon losses of the active chemicals and dilutions resulting from water entering from side drainage areas. Adjustments in the rate of flow in artificially controlled streams and careful regulation of chemical applications can result in very effective weed killing with the use of minimum amounts of materials.

On the other hand, herbicide materials which cannot be evaluated in their distribution by water color changes (note Figure 6) require careful calculations to obtain the desired rate of application.

Figure 6.—Rate of spray delivered indicated by discoloring of water. (Photo courtesy Cloroben Corporation)

Underwater weeds are highly objectionable in drainage areas which have very low rates of flow. Under such conditions the erratic secondary channels of flow are of little value in assisting with the uniform mixing of the weed-killing chemicals. Under such conditions some form of equipment transportation must be used to work out a pattern of uniform application of the herbicide. Dense underwater weed growths usually offer considerable resistance to common methods of propelling a surface craft. The so-called weedless propellers are effective under certain conditions. Paddlewheels so constructed that weed growth cannot tangle or adhere to the wheel have been used, an example of which is shown in Figure 7. Frog boats, marsh buggies and other special water craft will be effective within rather broad limits of use on waters filled with submerged weeds.

The distribution of liquids in still water and their adequate mixing into a body of weeds which it is desired to destroy may present a number of mechanical problems. If the chemical is

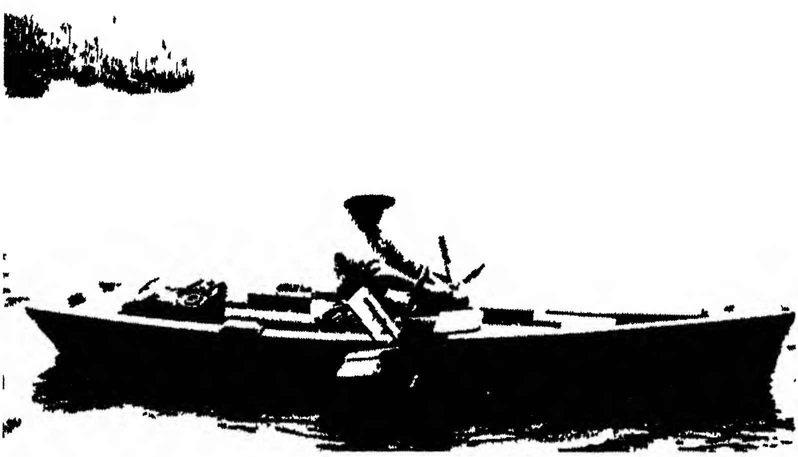

Figure 7.—Boat with paddle wheels. (Photo courtesy Cloroben Corporation)

more or less stable and has a high rate of diffusion or self-distribution through a weed mass, then a few points of application may be simple. A power spray rig can be used to supply the required chemicals through metering nozzles after mounting in a suitable transportation unit. Shallow underwater placement of a herbicide can be obtained when the nozzles are mounted on a vertical drop boom extension. When these are set at a moderate back angle clogging and pulling of the underwater weed growth largely will be prevented. The typical discharge from a chemical metering unit generally does not have sufficient velocity to create a real mixing effect in the volume of water to be treated.

High volume, high pressure pumps are capable of creating adequate turbulence adjacent to discharge into a large volume of water. The injection of the chemical mixture into the suction line of the large pump offers, on paper, a simple way of mixing chemicals into still water. In practice, however, there are many troubles due to the problems of transporting heavy power pump equipment under such conditions and, most important, the development of a suitable screen for the intake of the big pump.

Chemical applications with multiple nozzles at several depths can be obtained in a body of water by two general methods with minimum clogging in the weed growth. (1) The main boom with nozzle extension could be given a cycloid motion by mechanical devices attached to the transport unit. (2) A sled runner boom extension could place the nozzles in protected locations

Figure 8.—Spray nozzles attached to cutter bar of mowing machine. (Everglades Experiment Station)

above the lowest level of the runner but below the water surface at predetermined depths. In some cases, a circular saw in front of the sled runner would help prevent clogging and give uniform depth of operation.

Matured growths of water weeds, like land weeds, require excessive amounts of chemicals to obtain a kill. Mechanical mowing and covering the ground root area with a concentrated application of herbicide offers a new approach to this problem. Figure 8 shows a special spray boom, constructed at Everglades Experiment Station, with many nozzles attached to the rear of a mower cutter bar equipped with stub guards. This unit gave a low and effective spray placement under very dense vegetation that was difficult to cut with long-nosed mower guards.

Off-Center Spray Nozzles

The Spraying Systems Co., Bellwood, Illinois, has recently developed a series of nozzles having a wide off-center fan-spray distribution, the spray being of relatively large particle size, suitable for 2, 4-D surface contact spraying. These nozzles are available in a dual assembly called "Boomjet Nozzles." Through selection of size of orifice, liquid pressure, location above surface, etc., the assembly can give a wide range in rates and width of swath, for example, from 6 to 60 feet. This Boomjet, in single application, eliminates the need for a boom, which is a source of many difficulties when spraying in obstructed locations. The "OC" series of nozzles are so designed that they will pass relatively large particles of foreign matter in a spray solution. In practice, this means that less care is required in screening the water used in the spray mixture. Thus it may be possible for a boat spray unit to use water directly by suitable injection into a 2, 4-D spray mixture.

EFFECTIVE AIRBORNE SPRAY EQUIPMENT FOR WATER WEED CONTROL

A. E. HOLLAND[1]

A. E. HOLLAND

There are any number of variations in the equipment for aerial dispersal of herbicides. However, that which has come to be regarded as the more conventional is the light plane equipped with a tank, a blast-propelled pump and a boom arrangement with nozzles or other outlet.

By light plane, we refer to the small sportsman-trainer type with horse power ranging from 65 to 90 h.p. or the slightly heavier primary trainer type with horsepower ranging from 200 to 300. Tanks installed have a carrying capacity from 35 to 85 gallons of material and may be either of two general types. The internal tank which takes the place of one of the cockpits, is a permanent installation and has the advantage of carrying no additional drag to decrease the performance and maneuverability of the plane. The external tank, generally with a capacity of 83 gallons, is a detachable streamlined fuel tank converted for this particular use.

The pump, powered by a small fan extended into the propeller blast of the plane develops operating pressures ranging from 25 to 45 pounds depending on the number of nozzles, the size of orifice within the tips or other outlets if open boom arrangement is utilized.

For the express purpose of applying herbicides, check valves affording quick, positive cutoff is highly desirable as protection against a drool resulting in loss of material in areas not intended to be treated. In many instances, these "areas" may be susceptible crops and the results are disastrous. Nozzles, with various interchangeable tips, or orifices, are one means of chang-

[1]—World War pilot, Bartow, Florida, Mr. Holland is highly experienced in air service work for agriculture and did a substantial part of the flying involved in the early program of hyacinth eradication under Everglades conditions.

ing the overall rate of materials applied. Pressure, dispersal level and the swath flown are other factors in determining dosage. Generally speaking, the volume of material ranges from three to eight quarts per acre in droplet sizes of 150 to 200 microns.

The helicopter is considered unconventional but verv effective in its operation. Its advantages include slow and variable rate of travel plus accessibility to some areas considered hazardous and impractical for conventional craft. Its disadvantage lies chiefly in its cost and maintenance.

In order not to overlook the original equipment for aerial application of herbicides mention must be made of the familiar duster planes which were used extensively in some areas to apply 2, 4-D in dust forms. Too numerous complaints on extensive damage resulted in U. S. D. A.'s recommendation to the Civil Aeronautics Authority to ban this method and means of application. It is believed that leaky hoppers, inefficient hopper doors, and, in many instances, the operator's lack of appreciation of the potency of the material handled, are contributing factors in this decision. However, the principal reason usually given is the too frequent uncontrollable drift.

In conclusion, I might add that effectiveness of any equipment for the type of work under discussion depends largely on the operator—certainly airborne is no exception.

THE EFFECT OF CERTAIN HERBICIDES ON THE WATER HYACINTH AND OTHER AQUATIC PLANTS

F. W. zur Burg[1,2]

DR. F. W. ZUR BURG

Dr. E. J. Kraus of the University of Chicago is generally credited with having discovered the herbicidal properties of certain auxins in the year 1941. The first published work appeared in *Science* in 1944. This publication and subsequent work gave clear indications that a new and powerful weapon, useful in the control of noxious weeds, had been discovered.

The work on which this report is based was done in three phases: First, in the early spring of 1945 the writer, co-operating with Dean T. J. Arceneaux and Prof. Ira Nelson of the College of Agriculture of the Southwestern Louisiana Institute, initiated studies on the use of 2, 4-dichlorophenoxyacetic acid as a phytocide for the control of the water hyacinth. In the second phase, the writer continued these studies in 1946 as a collaborator with the United States Department of Agriculture. In the final phase, the writer acted as consultant with the New Orleans District of the United States Corps of Engineers.

Prior to 1945, Prof. Nelson had made several attempts to remove the hyacinth cover from a small two acre lake known as Lake Fletcher and located on the Southwestern campus. Mr. Nelson attempted crude mechanical methods first, but this proved unsuccessful. Later, he attempted to destroy the plants by spraying them with fuel oils. This second method also proved to be fruitless since the re-growth appeared to exceed the original stand of plants.

It will be recalled that very little had been published on the herbicidal properties of the phenoxy compounds in 1945. At that time, it was customary for investigators to dissolve 2, 4-D (the parent acid itself) in polyethylene glycol and to prepare the final

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—Presented by R. V. Allison

—Chemist, Southwestern Louisiana Institute, LaFayette, La

spray solution by mixing the glycol solution with water in the required amount. Because of this solubility difficulty, the writer first determined to examine the herbicidal properties of various compounds related to 2, 4-D with the hope that some of them would show better water solubility and perhaps better herbicidal activity. Dozens of these compounds were prepared in the laboratories at Southwestern. In the years that have followed that study, most of the compounds prepared have appeared on the market and a great deal of work has been done by many investigators on these commercial products.

Insofar as I can determine, Lake Fletcher was the first sizable body of hyacinth plants to be subjected to 2, 4-D compounds. This work was done early in 1945 and the results of the first work done were highly satisfactory. Because of the age of this first experiment, the lake was carefully watched and no hyacinths have been allowed to bloom on that body of water. The object in watching the lake has been to study the viability of the seed. During 1946 the hyacinths on the lake were allowed to grow but the blooms were hand picked daily. At the end of the 1946 season, about one per cent of the original area was again covered by hyacinths. The 1946 crop was destroyed with 2, 4-D. During this past year; i.e., the 1948 season, about two dozen plants were seen on the lake. From this, it would seem that under the conditions encountered in Lake Fletcher, the seed are not the serious consideration that they have been thought to be by some investigators. Plants of the size originally sprayed on the lake run between three and five hundred thousand to the acre. Thus the hyacinth cover of the lake decreased from about three quarters of a million to a couple of dozen in the period mentioned.

A number of things were learned that first year. For example, it was found that "tub tests" and green house tests did not always give the same results as did field tests. Just what caused these differences was not determined. It might be the fertility of the water or the oxygen tension of the water. I feel sure that there is a difference in glass filtered sunlight and that of the open field.

But during the winter, the greenhouse tests did give us indications and did prepare for the following year. During the 1946 season, the writer had the good fortune to work under the direction of Mr. W. L. Kephart of the U.S.D.A. Rather elaborate plans were made to decide just what was to be done and how the experiments were to be carried out, but I shall proceed to describe the work of that season and to give some of the results.

For one thing: a difference had been noted in the herbicidal activity of the water soluble salts of 2, 4-D and the oil soluble esters and parent acid. It was first decided to contrast the wetting properties of the carrier oil in the oil emulsion ester sprays with the straight aqueous solutions of the 2, 4-D salts to which wetting agents were added. For these tests a spray solution having a concentration of 1000 parts per million of 2,

4-D acid or its equivalent as an ester or salt was used. To make the tests more uniform, spray applications were made at the rate of 200 gallons per acre.

Arbitrarily, the butyl ester was taken for a standard since, in oil emulsion, this compound was known to have good herbicidal properties. The average of several tests indicated that when this material was used, good epinasty resulted at the end of about 24 hours and that at the end of eight weeks the recovery or re-growth was about 2 per cent. It might be mentioned at this time that some herbicides give good immediate results, or apparently give an immediate kill; yet, when the plants are examined it is found that the rhizomes have not been affected. Of course, the final results of such a herbicide are worthless. It is believed that a great many erroneous reports have found their way into print because the results have been read too soon. Thus, the eight week period was taken as the minimum final time of final reading and most results have been watched for four months.

Contrasting with the butyl ester, the sodium salt in the above mentioned concentration and quantity was used. It was found that when the salt and water *alone* were used that there was only slight epinasty at the end of 24 hours and that there was about a thirty per cent recovery at the end of eight weeks.

Next, a series of tests were made by adding various surface activators or wetting agents to the solutions of the sodium salt. About three dozen or more commercial wetting agents were tested. This list includes soda ash, soap, sodium salts of sulfonated petroleum hydrocarbons, sodium lauryl sulfate, mannitan monolaurate and many others. The soda ash increased the ability of the water to film the surfaces of the hyacinth leaves but did not appreciably increase the kill. With about three pounds of soap per hundred gallons the epinasty was better at the end of one day and the kill was slightly better at the end of eight weeks. A great many commercial wetting agents gave excellent results. Among them might be mentioned the Atlas' Company's "NNO," Monsanto's "Aresket 300," Rohm and Hass' "Triton K-100," du Pont's "IN-181-P" and Atlantic Refining Company's "Ultrawet."

It will be noted that in subsequent tests the wetting agent "Ultrawet" has been used rather extensively. This does not mean that it necessarily gives the best results, but rather that it gives an excellent herbicidal solution when acting as a wetting agent with the sodium salt and that it is relatively cheap and that only a small quantity is required.

It was found that the use of excessive amounts of the surface activators caused the herbicidal solution to drain too rapidly from the leaves and that a small amount did not give good wetting nor materially increase the kill. By trial and error, it was found that Ultrawet is best used in a concentration of from six to eight ounces per hundred gallons of 1000 p.p.m. sodium salt spray solution.

During the 1946 season, attempts were made to determine the length of time necessary for the hyacinth to absorb a lethal dose of 2, 4-D. It is obvious that such studies were necessary since a rain following a spray application would tend to wash the herbicide from the plant leaves.

An early set of experiments was carried out in thirty gallon wooden tubs. Each tub contained a dozen or more healthy water hyacinth plants, and the water in each tub contained about two teaspoonfuls of concentrated fertilizer.

In each experiment the hyacinth plants were removed from the water and inverted. While in this inverted position the plants were thoroughly sprayed with the particular herbicidal formulation being worked with. After various intervals of time, the inverted plants were thoroughly washed with large amounts of water. The amounts of water used corresponded to an almost impossible weather situation, since in terms of rainfall the wash water would be about six inches of rain per hour.

It was observed that time of contact required for almost all oil emulsions was practically zero. It is safe to say that five minutes of contact was sufficient in the tub experiments. This, it is believed, is due to the fact that it is almost impossible for a fresh water wash to remove completely the oil film from the leaves. In a field test, a plot was sprayed with an oil emulsion of an ester during a light rain. Practically a hundred per cent kill resulted. In another test, a quarter acre plot was sprayed with 100 gallons of the butyl ester of 2, 4-D in oil. The concentration as 2, 4-D acid equivalent of the solution was 0.1 per cent. Within twenty minutes after the spraying was completed, the plot was washed by the heavy rain of a thunder shower. Apparently, there was no marked difference in the amount of kill obtained in this plot and the kill obtained under dry conditions.

In the tub tests, when water solutions of the sodium salt were used as the herbicidal spray, the contact time appeared to be about ten minutes. That is, some plants were killed after a five minute exposure, whereas some required as much as fifteen minutes. When wetting agents were added to these aqueous sprays, the average time required was about five minutes.

In a field test, a quarter of an acre of hyacinths was sprayed with 100 gallons of the sodium salt of 2, 4-D having an acid equivalent concentration of 0.1 per cent. This amount of solution contained six ounces of Ultrawet as a surface activator. The spraying was followed in about 45 minutes by a drenching rain. At the end of eight weeks the per cent kill was only about 40 or 50 per cent.

It is believed that oil emulsions of 2, 4-D may be used during light rains and still retain their herbicidal activity. Straight aqueous solutions probably should not be used if rain is anticipated within a few hours, or perhaps if cumulus clouds are forming and turning dark.

From the view point of the U. S. Corps of Engineers, it

would be desirable to have an herbicide that would not only kill the hyacinth, but it would be still more desirable to have a material that would destroy the plant and cause it to sink rather rapidly in the water. The Engineers are particularly interested in this since their main objective is to open waters to navigation and the dead plants offer practically the same hazard to navigation as do the live plants.

In 1946, methods of bringing about the accelerated sinking of the hyacinth plants were worked on. At first, it was thought that by increasing the fertility of the water the organisms which bring about the decomposition of the plants might be stimulated. Repeated tests gave no hope for this method. The waters were fertilized with large and small amounts of commercial fertilizers and with variations in the nitrogen, phosphorus, potash ratio. Barnyard manure was also applied to the dead plants with negative results.

A few other things were done in 1946. For example, dyes were added to the spray solutions. With such solutions it was hoped that the plants could be marked so that the spray operator might easily see the results of his work. Some of the purple dyes gave good desults, but when the amount of dye used was considered and the cost of this dye was added to the cost of the solution, it was decided that the use of dyes on a large scale was not feasible.

One fact might be mentioned in connection with the desirability of marking the work of the spray operator. It was noticed that the wetting agents (or the carrier oil in the ester sprays) served as a marking agent. The leaves of the hyacinth are so completely wetted that they reflect considerable incident light. Thus, the wet leaves stand out in contrast with the leaves remaining unsprayed. As for an inspector checking on the work of a spray rig operator—if a good 2, 4-D formulation is used the inspector need only wait 48 hours before making his check and he can then most certainly tell by the epinasty of the plants where the operator was lax in his application.

During the summer of 1947, the writer was privileged to work as a consultant with the New Orleans district of the U.S. Corps of Engineers and to be associated in this work with Mr. W. E. Wunderlich whose work on mechanical destruction is well known.

One of the things attempted in this season was to continue the work on "sinking agents." I might mention that between 1946 and 1947 a great many water hyacinth experts developed in Louisiana and that 2, 4-D was discovered and re-discovered at least fifty times. We also developed a number of "sinking experts" during that period. When some of these claims were investigated, it was found that "sinking" as defined by the new expert consisted of the sinking of the plants to the water level and not a total submergence.

One of the interesting "sinking agents" developed in this

period was Schweitzer's Reagent. The writer does not doubt that this reagent will dissolve the cellulose of the water hyacinth since this is the notable chemical characteristic of cuprammonium hydroxide. But, considerable amounts of the reagent would have to be used per acre and the material is expensive. It is also true that soluble copper is very toxic to both plant and animal life. Of course, we were trying to use a material that was relatively non-toxic to fish and other aquatic life. For this reason, the writer did not use Schweitzer's Reagent except in tub experiments.

Remembering that the paper and pulp industries have settled on certain chemical reagents for the separation of cellulose and the lignin binder in the production of their product, it was thought that some of the agents might be of use in breaking up the water hyacinth plant. As a result, 2, 4-D solutions containing various amounts of caustic soda were tried both for herbicidal action and as a "sinking agent."

To briefly summarize the results: It was found that the caustic digested the waxy surface of the leaves and stems and allowed subsequent rotting to proceed more rapidly. It is not believed that caustic solutions of less than 1 per cent NaOH by weight have very much effect but that solutions of caustic in which the alkali content is between one and three per cent are fairly satisfactory as a decomposition accelerator or "sinking agent." For example, when a plot was treated with a solution consisting of 1000 p.p.m. of the sodium salt of 2, 4-D and 2.5 per cent sodium hydroxide, over half the plants submerged and sank within 40 days. This is a considerable improvement over the normal period of months. The writer believes that this is not necessarily the answer, but that continued studies along this line should be made. Reagents other than caustic soda might be used.

As for the toxicity of caustic soda to fish: It is not necessary to apply more of the solution than that amount required to wet the leaves of the plants. The digesting action is almost immediaate and can be observed. After exposure to the atmosphere, the caustic is soon converted to the carbonate. This compound, if allowed to get into the water, does not appear to bother the aquatic life.

Further attempts were made to activate the water soluble 2, 4-D salts and to bring them to the herbicidal activity of the oil soluble esters. It was observed on small plot operations that the addition of mineral acids to 2, 4-D solutions appeared to increase the activity of the herbicides. Jones mentions this fact in his patent. By trial and error, it was found that the addition of about four or five ounces of sulfuric acid to 100 gallons of spray solution containing 1000 p.p.m. of the sodium salt gave excellent results.

It might be said that the addition of the acid to the sodium salt of 2, 4-D simply forms the parent acid of 2, 4-D and this is

true. It might be argued that the solution should be made with 2, 4-D itself and then less acid would be required and this is also true. But, the 2, 4-D acid is hard to dissolve in water whereas the sodium salt can be dissolved with ease; thus, it is easier for the operator to start with the salt and to waste a small amount of acid.

In all cases when five or six ounces of sulfuric acid were added to the 100 gallons of 0.1 per cent 2, 4-D sodium salt solution to which a few ounces of Ultrawet had been added, the percentage kill was noticeably better; in fact, such spray solutions are as effective as the oil emulsion ester formulations and are much cheaper.

It might be well to add a few words about droplet or particle size of the sprayed solutions. During 1947 we tried various types of sprays to determine effectiveness of each. At first, it seemed to make little difference as to whether we used a solid, heavy stream of the herbicidal solution or a fine fog. With plants of moderate size there is probably no difference. However, when the treated plants were very high; that is, over three feet in height, the fog sprays did not work as well. Apparently, the fine fog can not penetrate into the depths of the heavy vegetative growth.

Of course, small droplets do not settle as fast as large drops and with fogs more wind drift may be expected. The Louisiana Conservation Department had some unfortunate trouble with wind drift of dusts of small particle size. In some of our experiments with small drop sizes, using aqueous sprays, we noticed damage to adjacent vegetation even when the utmost care was used to eliminate or control the drift.

A lot of other things were done. The list of known herbicides, organic and inorganic, were again tested. Mixtures of various herbicides were tried. But, the story is long and the results, in most cases were unsatisfactory.

The effect of herbicides on alligator weed was also considered. As is known, 2, 4-D will easily control this pest when it grows on land, but the same phytocide is unsatisfactory when this plant is growing in water. However, a fair control of alligator weed was obtained by making heavy applications of emulsifiable ortho dichlorobenzene. Also, some hope was given by two experiments in which an emulsifiable mixture of carbon tetrachloride and oil, containing 2, 4-D was used as the spray solution. This emulsion is heavier than water and settles. It will be admitted that both of these treatments are harmful to aquatic fauna.

To summarize, perhaps a few comments and a few personal opinions should be expressed. We all know that the hyacinth problem is big and that vast areas are concerned; but we also know that immeasurable benefits would follow the elimination—or perhaps, I should say—the control of this weed. We might start with the cost of materials. In many cases we have been paying too much for our equivalent 2, 4-D.

In order to whip the hyacinth problem in Louisiana, perfect co-ordination of known mechanical and chemical methods will probably be required. It is not intended that the two methods should be contrasted; for, they are each adaptable to entirely different situations. The saw boats can not get close into shore and therefore always leave a fringe to re-infect the streams. At the same time, it is almost impossible to drag heavy spray equipment through the hyacinth jams without first having a way cleared by the saw boats, and certainly no chemical can open the streams as rapidly as the saw boats can at the present time.

Mention has been made of the fact that the hyacinth has been practically eliminated on a small lake on the Southwestern campus. But this was just a two acre plot. Near Lake Arthur Louisiana, we practically eliminated the hyacinth over a vast area. In this area, the waters flow in both directions. That is, the flow depends on whether the gulf or the swamps are exerting the greater water head.

The writer believes that we have got to use chemicals if we want to accomplish any permanent good. Let us suppose that it would cost as much to chemically spray an area as it costs to mechanically saw the same area. The mechanical process must be repeated year in and year out and the cost remains constant. But with the chemical method the cost decreases each year and would eventually disappear.

It is a big problem, but I am sure "it can be done."

THE CONTROL OF AQUATIC WEEDS BY CHEMICAL METHODS IN THE FLORIDA EVERGLADES

CHARLES C. SEALE

INTRODUCTION

Since the first tests on the Hillsboro canal during the late spring of 1945 with 2, 4-D a considerable amount of experimental work has been done on the determination of suitable chemical methods for the control of water hyacinths and other aquatic weeds by several persons and agencies in the State of Florida.

The Jacksonville office of the U. S. Army Engineers, War Department under the direction of Colonel Teale has made a thorough investigation of the extent of the infestation of the waterways of Florida with the more important water weeds, and has sponsored an extensive program of experimental work for the eradication of these pests. In a certain phase of this work, Evans (3), working out of that office, gave cooperative assistance to the project.

The systematic eradication of water hyacinths in the Florida Everglades was commenced in 1946 by the Everglades Drainage District. This work, largely by air spray, proved so successful that it was later extended to include a large scale control of these pests in the principal arterial canals of this area. Johnson (5) has given the Board of Commissioners of the Everglades Drainage District a comprehensive report of the scope of this work and the results obtained during the period 1946 to 1948 (See Appendix, pp. 212-219)

Hilderbrand (4) experimented in 1945 with 2, 4-D for the control of water hyacinths, as we now also learn did Dr. F. W. zur Burg (7) and his associates in Louisiana during the same year through the paper he has given on this Symposium.

During the period under review a considerable amount of experimental work also was done by Allison and Seale (1) at the Everglades Experiment Station on the control of water weeds.

From November 1945 until June 1948 particular attention was paid to the control of water hyacinths, *Eichornia crassipes* Solms. More recently, however, and especially since the successful removal of larger quantities of water hyacinths from the drainage system of the Florida Everglades as a result of the untiring efforts of the Everglades Drainage District, work has been commenced on the control of other aquatic plants, both of the submerged and emergent types, which tend to take the place of water hyacinths. Many of these plants already have clearly demonstrated their ability to become very serious pests, and it

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seems likely that the working out of suitable methods for their control may be more difficult than in the case of the water hyacinth. In the initial stages of this more recent work by the Everglades Experiment Station, special attention has been focused on chemical methods for the control of certain submerged types of aquatic plants such as *Najas* sp., *Ceratophyllum* sp. and *Anacharis* sp. very common water weeds which produce dense growths in many of our canals and farm ditches.

In this paper is presented an outline of experiments with chemical methods for the control of water hyacinths, and some preliminary findings of work recently commenced on certain submerged aquatic plants.

THE CONTROL OF WATER HYACINTHS

Description of Plant

The water hyacinth, *Eichornia crassipes* Solms., is a member of the pickerel weed family, *Pontederiaceae*. This plant is generally found growing in areas of fresh water such as ponds, lakes, canals, streams and rivers. It can tolerate somewhat brackish water, but is not very winter hardy. In the Everglades area, plants grow very vigorously and attain frequently a height of 50 inches, and a density of 200,000 per acre.

Propagation generally occurs vegetatively by means of stolons, but a few plants are also produced from seed, when suitable conditions exist. The young plants have bladder-like petioles which are their principal means of flotation, but as they grow older the petioles become slender. As the plants continue to grow to maturity they develop rhizomes which may be as long as 10 inches.

Distribution of Hyacinths in Florida

A recent survey conducted by the War Department, U. S. Army Engineers, indicates that Florida is the major area of infestation in the Southeastern section of the United States and that about 63,000 acres in the State are now infested with this obnoxious pest. The areas of greatest infestation are the Kissimmee, St. Johns and Withlacoochee rivers, which account for about 60 percent of the total area involved.[1]

An extensive program of eradication by the Everglades Drainage Board has now considerably reduced the incidence of this pest in the principal arterial canals of the Everglades drainage system, but the plant is still very prevalent in the smaller canals and farm ditches of this area.

Benefits to Be Obtained From the Control of Water Hyacinths

In the flat agricultural lands of the Florida Everglades,

[1]—Reported on in detail in this same volume of the Proceedings, pp. 21-28, by J. A. Hammack.

where the elevation rarely exceeds 16 feet above sea level, the most important benefits to be obtained from the control of water hyacinths are improved conditions for flood control, drainage and irrigation.

Flood damage caused by hurricanes in South Florida has been very great during the past two seasons, and any means of reducing this hazard is of paramount importance to the agricultural interests in this area. Furthermore, any improvement in facilities for the removal of flood waters will obviously also benefit the normal practices of drainage and irrigation.

It has been estimated by Clayton and Neller (2) that dense growths of hyacinths in the main canals of the Florida Everglades are capable of reducing the discharge capacity by about 50 percent, and also that the transpiration rate from such a cover will be about three to four times the evaporation rate from open water surfaces. The former condition severely impedes drainage, and the latter causes heavy losses of water during the dry season when irrigation is sometimes practiced.*

The presence of large masses of water hyacinths have very harmful effects on fish and wildlife, and the removal of the plants would greatly increase productivity from these sources.**

Many of our lakes and streams have high potential values as places of recreation for fishing, boating and swimming, if they were freed from undesirable aquatic weeds. Also the large scale removal of the plant would greatly facilitate commercial navigation, and would reduce the cost of water treatment for public use and malarial prevention.

Methods of Control With 2, 4-D

(1) *Earlier Experimental Work*

During 1946, a considerable amount of experimental work was done with 2, 4-D for the control of water hyacinths. Allison and Seale (1) presented the results of several tests made by the Everglades Experiment Station, and Evans (3) reported on hyacinth control investigations performed in cooperation with the War Department, U. S. Army Engineers.

In these early tests comparisons were made between spraying and dusting, and the latter method was found to be uneconomical and impractical under Everglades conditions even before it was outlawed by the Federal government.

Different chemical forms of 2, 4-D also were applied at rates ranging from 0.4 to 6.0 pounds of 2.4-D acid equivalent per acre in aqueous sprays of high gallonage, that is 100 to 200 gallons per acre.

The chemical types of 2, 4-D used in these tests included the

*—These relationships reported on in detail by D. B. Bogart, pp. 32-52 this same volume of the Proceedings.

**—These relationships reported on in detail by J. J. Lynch, pp. 58-65 of this same volume of the Proceedings.

inorganic salts (sodium, ammonium and potassium), the esters (butyl, isopropyl, methyl and ethyl) and the amine salts (triethanolamine and alkanolamine).

The results obtained from these earlier tests indicated that the esters and amine salts produced somewhat stronger effects than the inorganic salts of 2, 4-D, and that good herbicidal results were obtained from the application of 1.3 to 1.6 pounds of 2, 4-D acid equivalent in the form of the ester or amine salt.

The above mentioned experiments with 2, 4-D applied by ground spraying equipment in aqueous solutions were followed by trials involving the application of 2, 4-D by airplane at the low gallonage rate of about two gallons per acre. These trials indicated the desirability of using the oil miscible ester instead of the water soluble amine salts.

This latter method proved very satisfactory, and as a result large scale control operations for the removal of water hyacinths from the arterial canal system of the Everglades were initiated by the Everglades Drainage Board.

At the present time a large quantity of the hyacinths have been removed from many of the principal arterial canals in this area, and a method of patrol by boat has recently been set up to take care of remaining fringes along the banks of the canals.

(2) *More Recent Work:*

From the middle of 1947 until the present time a great deal of attention has been paid to the application of 2, 4-D at the low gallonage rate of approximately six gallons per acre by ground spraying equipment, and much of this work has been carried out with equipment loaned to this Station or especially constructed by the staff of the Agricultural Engineering Division of the Everglades Experiment Station. This method of spraying has many advantages over the more conventional type of high gallonage spray equipment.

The most important of these are the much lower initial cost of the equipment, its lightness of handling and the greater economy in the time and cost of applying the spray materials.

Attention also has been given to a comparison of herbicidal effects of these low gallonage sprays with those of higher rates of application.

In March 1947, an experiment was laid out which was designed to test the effects of applying 2, 4-D in the form of the butyl ester at rates ranging from 2 to 200 gallons per acre.

Four weeks after spraying, representative samples of hyacinth plants were removed from the plots in order to determine the effects of treatments on the growing points and rhizomes of the hyacinth plants.

The results of this experiment are presented in Table I from which the following conclusions can be drawn:

(1) the low gallonage oil sprays were far superior to the higher gallonage aqueous sprays.

TABLE I—RESULTS OF SPRAY TESTS

Rate Application of Diluent		1 lb 2, 4-D Acid per acre		2 lbs. 2, 4-D Acid per acre	
Water Gals p.a.	Oil Gals p.a.	% Growing Points Dead	% Rhizomes Decomposing	% Growing Point Dead	% Rhizomes Decomposing
	2	94.0	88.0	100.0	98.2
25		92.7	78.2	98.4	91.8
50		86.5	71.2	96.8	90.5
100		86.3	60.8	98.2	83.9
150		85.4	68.8	96.7	83.6
200		86.3	70.6	94.6	82.1

(2) with the aqueous sprays, better results were obtained when the rate of application was 25-50 gallons per acre than when it was 100-200 gallons per acre.

On the basis of this and many other results subsequently obtained from numerous trials, we consider that the most effective control of water hyacinths can be obtained by spraying either by airplane or ground equipment with an ester of 2, 4-D at the rate of 1.0 to 1.5 pounds of the acid equivalent in No. 2 diesel oil at approximately two to six gallons per acre.

THE CONTROL OF CERTAIN SUBMERGED AQUATIC PLANTS

TYPE OF PLANTS USED IN THE EXPERIMENTS

In the initial stages of this most recent phase of the experimental work on the control of submerged aquatics, which is being carried out by the Everglades Experiment Station, two types of plants namely, *Najas* sp. and *Ceratophyllum* sp., were selected for detailed study. These plants are commonly found making dense growths in the canals and farm ditches of the Everglades region of Florida.

CHEMICALS USED IN THE TREATMENTS

The herbicidal effects of the following chemicals were compared in our tests:

(1) a chlorinated benzene
(2) seven different types of solvent napthas
(3) hexachloroethane dissolved in a special type of oil derived from coal tar and diluted (1:1) with No. 2 diesel oil.

The solvent napthas used in the tests had the following range of physical properties:

Flash Point	90-250° F.
Mixed Aniline Point	51-135° F.
Kauri-Butanol Value	100-118 ml.
A.S.T.M. Distillation	
Initial Boiling Point	276-425° F.
50% Point	282-504° F.
95% Point	286-614° F.
Final Boiling Point	302-740° F.

Experimental Procedure

During the early part of September 1948 small scale experiments were laid out in the greenhouse at the Everglades Experiment Station. In these tests plant material of *Najas guadalupensis* (Spreng.) Morong and *Ceratophyllum demersum* L., were placed in water-filled glass containers and were treated with the chlorinated benzene, the solvent napthas and the hexachloroethane mixture at concentrations of 100 and 200 ppm.

An emulsifying agent, Triton x-100, was added to all the treatments involving the use of the solvent napthas and the hexachloroethane mixture at the rate of five percent by volume. The results of these tests are dealt with in the following section.

At about the same time two experiments were laid out on a heavy mixed growth of *Najas* sp. and *Ceratophyllum* sp. in a canal located in the Clewiston area to test the herbicidal effects of the above chemicals under actual field conditions. Very unfortunately, however, all of the experimental plots were completely destroyed by the flood conditions which accompanied the hurricane of September 20-21, 1948, and it was decided that no further attempts should be made to set out field trials until the hurricane season had passed.

Results

The results of the greenhouse tests indicate that several of the solvent napthas, with added emulsifier, showed considerable signs of promise, and gave results that were practically as good as that of the chlorinated benzene for the range of values tested. It should be noted, however, that when the emulsifier was not added to the solvent napthas as indicated very poor results were generally obtained.

The hexachloroethane mixture did not give as good results as the other types of chemicals. The manner in which the hexachloroethane was used in these tests was suggested by a commercial supplier, but it may be possible to improve its effects by altering the method of application.

Chlorinated benzene formulations have commonly been used in the past for the destruction of growths of submerged aquatic plants. However, the recent work of Moran and Shaw (6) has demonstrated that solvent napthas also have a strong phytocidal action on certain water weeds.

No definite price quotation appears to be available yet for the solvent napthas, but indications are that their cost will be considerably less than the chlorinated benzene products. Consequently the use of the solvent napthas for the control of submerged aquatic weeds may prove to be both satisfactory and economical.

In the determination of the treatment effects in our greenhouse tests, particular attention was paid to the following conditions:

(1) the length of time taken for the treated plant material to sink to the bottom of the containers.
(2) the commencement of decomposition of the dead plant material and the rate at which it progressed to the final stage.

Quite obviously more attention was paid to conditions (2) above than to (1).

It is thought that the method of small scale testing in the greenhouse previously outlined could be utilized advantageously for a rapid evaluation of a large number of herbicides intended for use in the control of certain submerged aquatic weeds. After the best herbicides had been screened out in the pot tests, then this lesser quantity of good materials could be included in large scale field tests, which would be considered as the source of more conclusive results.

Summary

(1) The work which has been done during the period 1945 to 1948 for the control of water hyacinths and other aquatic weeds by several persons and agencies in the State of Florida is reviewed.

(2) A method for the control of water hyacinths, based on several years of experimental work, is presented. This method involves the spraying of the plants, either by airplane or ground equipment, with an ester of 2, 4-D at the rate of 1.0 to 1.5 pounds of 2, 4-D acid equivalent in No. 2 diesel oil at approximately two to six gallons per acre.

(3) Since the large scale removal of the water hyacinths from many of the arterial canals of the Florida Everglades by the Everglades Drainage District, other aquatic plants have clearly demonstrated their ability to become obnoxious pests. Consequently particular attention is now being paid by the Everglades Experiment Station to methods of control for the submerged aquatic weeds, *Najas* sp. and *Ceratophyllum* sp. Preliminary results of pot tests indicate that certain solvent napthas gave a satisfactory control of these plants. This control was practically as good as that obtained with a chlorinated benzene product.

(4) The work on submerged aquatic weeds at the Everglades Experiment Station is being continued.

Acknowledgments

Grateful acknowledgment is made to Dr. R. V. Allison, Vice Director, Everglades Experiment Station, for very helpful advice and assistance rendered during the investigation.

The writer is also indebted to Mr. John W. Randolph and Mr. William A. Desnoyers (deceased) of the Agricultural Engineering Division of the Everglades Experiment Station for assisting

with the construction and use of the spray equipment in some of the more recent phases of this work.

The cooperation of the following companies in supplying the various chemicals used in these tests is greatly appreciated: American Chemical and Paint Co., Ambler, Pennsylvania; R. J. Brown Co., St. Louis, Missouri; Chipman Chemical Co., Bound Brook, New Jersey; The Dow Chemical Co., Midland, Michigan; E. I. DuPont de Nemours Co., Wilmington, Delaware; Esso Standard Oil Co., New York, New York; Fine Organics Inc., New York, New York; Pennsylvania Salt Manuf. Co., Philadelphia, Pennsylvania; The Sherwin-Williams Co., Chicago, Illinois; Standard Agricultural Chemicals Inc., Hoboken, New Jersey; The United States Rubber Co., New York, New York; Wilson Spraying and Supply Co. Inc., West Palm Beach, Florida.

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CONTROL OF SUBMERGED AND EMERGED WEEDS IN THE FEEDER CANAL OF THE WEST PALM BEACH WATER SUPPLY SYSTEM

RUDOLPH P. TOMASELLO[1]

This is a report of a chemical weed control project conducted in the West Palm Beach Water Company's canal for the control of submerged and emerged aquatic plants that were impeding the water flow. This canal was dug to drain water from the Loxahatchee slough into Lake Mangonia which serves as the reservoir for the West Palm Beach Water Company.

While chemical control of submerged aquatic weeds in irrigation systems in the West has been in use for some time, and has also been used in this State, there are still many factors in the use of chemicals for this purpose that are not too well understood.

There were many species of aquatic plants in the canal but the most prolific and troublesome plants were Eelgrass (Vallisneria americana), the White Water Lily (Nymphaea odorata) and the Yellow Water Lily (Nephar advena).

It was suggested by several authorities that two applications would be necessary because of the density of the weed growth. In this case it proved to be correct.

At the time of the first application, the canal averaged about thirty feet across and its greatest depth was about four feet. The water level was extremely low and a static water condition existed. Certain portions of the canal were completely choked by the weed growth, so much so that we found it necessary to put men on each bank to pull, with ropes, the rowboat that held the sprayer. A spray boom was used that reached from shore to shore. The even pull of the men on the opposite shores kept the boat in the middle of the canal, making for a uniform application.

A gear-type pump was used but in order to develop greater pressure this was supplemented by a plunger-type. The plunger-type pump became inoperative very soon because the chemical used destroyed the plungers and packing. It was necessary to use Neoprene hose as the chemical caused disintegration of natural rubber.

The material used for the first application was Benoclor-3, which was found to have certain disadvantages. This material is very hard to emulsify, requiring pressure up to 200 pounds for good emulsification, and even after emulsification it had a tendency to break and settle quickly to the bottom of the canal.

The average spray pressure used was about 30 pounds. It appeared that the best results were obtained when the Benoclor stayed in suspension and in contact with the weeds the longest

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time. The best nozzle position was found to be just under the water, as a better emulsion and distribution of the chemical was obtained in this position. When the nozzles were lifted clear of the water, little if any of the material would emulsify and it formed clear liquid drops that fell to the bottom of the canal.

Benoclor is caustic to the skin and when emulsified with water it is even more so. One operator stepped into treated water and was burned severely. The symptoms were of a severe sunburn, the skin peeling, causing much personal discomfort.

Starting at the head of the canal we worked slowly downstream. We treated 13,800 feet of the canal which carried us to the first control gate. 200 gallons of Benoclor-3 were used. The chemical seemed to work very slowly and after two weeks the kill appeared very disappointing, though some of the weeds were breaking loose from the canal bottom and forming floating masses of dead plants. It became apparent that the chemical was still active when bare feet and hands were burned slightly when a worker waded into the water to secure a soil sample from the canal bottom for analysis.

At this time an airboat was used in an attempt to break loose the dying weeds from the canal bottom. Eight half inch chains fifteen feet long were placed at the stern of the boat acting as streamers. The airboat moved back and forth over the canal many times to do this job. This procedure was beneficial and it was soon apparent that the chemical was more effective than it had appeared at first. The dragging seemed to stir up the Benoclor and it killed weeds not affected by the initial application. Since the Benoclor-3 did not stay in suspension for long and since there was little if any current, no weeds were killed beyond the treated area.

At the time the submerged weeds were being treated with the spray boom under water, the water lilies were sprayed over the top with a hand gun. This method of applying Benoclor to the lilies was of little value as only a temporary leaf burn developed and several weeks after the application, the burned leaves were scarcely noticeable. Neither method of treatment appeared to be of much value in killing the water lilies, at least not at the time. However, later the lilies in the middle of the canal started to disappear, opening up a passage for a boat. It was thought that this was probably due to a combination of the chemical and the dragging.

We had been led to believe that inasmuch as the game fish were very active, they would move out of the treated water into the lake and would not be affected by the treatment, whereas the sluggish Garfish would remain in the treated water and would be destroyed. The results were not exactly as predicted. Large numbers of Bass and other game fish were destroyed while a smaller percentage of the Gars were killed. Many water Moccasins and soft shell turtles were also destroyed. The fish began to die very soon after the treatment and continued for

several days. These fish floated to the top of the water and were removed with dip nets and seines by a crew of men.

About a month after the first treatment a second application was made. This time Benoclor-3C was used and appeared to be superior to Benoclor-3. During the interval between the first and second spraying, daily rains had raised the canal level about one foot and there was considerable water flowing. The canal had by this time widened and the boom was not sufficiently long to reach from bank to bank. However, we expected the chemical to disperse and in the fast moving current cover the entire water area. Where the canal bottom was very shallow for three or four feet out from the shore, there was little current and the chemical did not cover this area thoroughly. There was a noticeable line along the canal bottom between the treated area and the portion that the spray did not reach.

Benoclor-3C emulsified in the water much better and stayed in suspension much longer than did Benoclor-3. As a result of this a much more rapid and superior weed kill was obtained. It was estimated that about 80 per cent of the weeds were killed by the two treatments, the submerged weeds being much better controlled than the lilies. Due to rapid flowing water, weeds were killed for more than a mile below the point where the spraying stopped. The second spraying covered the same area as the first spraying. There was a much greater volume of water in the canal at the time of the second spraying and though we applied 25 gallons less material at this application, the results obtained from the Benoclor-3C were superior in every respect.

Benoclor-3C also was destructive to game fish and was more destructive to the Garfish than the Benoclor 3. It was interesting to note that fish life was quickly reestablished. Only one week after the last application large Bass were being caught in large numbers and two weeks after the application, we saw one man with a string of fourteen Bass taken from the treated area. Now, several months after the treatment, the canal is again stocked with fish that have come in from the lake, the sloughs and ponds. It is the opinion of many keen observers of fish life that after the high water which is now present recedes, the fish will be as abundant in the canal as they were before the treatment.

It appears that an annual application of Benoclor 3C will give a satisfactory control of aquatic weeds, at least for the submerged weeds that now are found in this canal.

SOME WATER QUALITY RELATIONSHIPS OBSERVED UNDER EVERGLADES CONDITIONS IN THE COURSE OF STUDIES OF POSSIBLE AFTER EFFECTS FOLLOWING HYACINTH TREATMENT WITH 2, 4-D

T. C. ERWIN[1]

With the cooperation of the U. S. Fish and Wild Life Service a study was inaugurated to determine the effect of hyacinth eradication with 2, 4-D on the fish life of the Everglades, and to determine the cause of frequent fish kills observed in these canals.

Methods used in this study were chemical analysis of the water (dissolved oxygen, oxygen demand, hydrogen sulphide and pH), comparative fish trapping, and live fish boxes.

It has been shown that the 2, 4-D used to kill the hyacinths will have no toxic effect on fish when used in any reasonable quantity. The question to be answered here is: what is the effect of the decaying hyacinths and the effect of their removal?

It was found that during the summer months the water in the canals is generally unsuited for normal fish life. This is true except for regions near the lake when there is a large flow of good water coming from the lake into the canals. The canal water is usually very low in dissolved oxygen, and has a high oxygen demand, and at times has a high hydrogen sulfide content. No doubt there are a number of other reduced gases which occur in the water along with H_2S which have toxic effects on fish. During this summer the dissolved oxygen in one canal at one sampling point about six miles from the lake was always below the level considered necessary for normal fish life and at times could not be detected at all. The H_2S content of some canal samples was greater than 30 p.p.m., 10 p.p.m. of H_2S in water is considered very toxic to fish.

Careful observations and comparative trapping indicate that during the time of this study (June to November) the only aquatic life in the canals at a considerable distance from the lake (over four miles) consisted of turtles, gars, salamanders (Siren Lacertina), and top minnows. These salamanders were quite numerous and some of the specimens trapped were two feet long.

However, the population of the smaller drainage ditches in the farms was quite different. In the spring the aquatic population consisted of bass, brim, catfish, suckers, gar, and top minnows. As the summer rains began and the water from the soil was drained into these ditches the fish life began to suffer. First the bass population started to decline and after each heavy rain dead fish were observed floating in the canals.

[1]—Assistant Chemist, Everglades Experiment Station, Belle Glade, Florida.

This year on the first day of November there was an unusually heavy rain which put the finishing touches on what the summer rains had been doing. After this heavy rain the only apparent survivors in the farm ditches were gar and top minnows. Since then the top minnow population has been increasing rapidly.

We can surmise a broad picture of the whole situation something like this: the lake is the main area of survival during the summer months when the canals are contaminated with toxic soil water. As this condition improves the fish move out into the canal system to feed on the accumulated population of top minnows, where many are trapped in the farm ditches and killed by the toxic water during the summer.

When water stands under hyacinth mats for any length of time the water will not be suitable for normal fish life. Therefore, the fish tend to move to the farm ditches which are kept free from hyacinths. Fish will inhabit the canals under hyacinths when there is a flow of water from the lake. As a matter of fact they are very quick to follow good water to new areas in search of food. This can be seen by the fact that if, when the lake is higher than the canals, a lock is open for a short time and then closed again, dead and sick fish will begin to appear on the surface of the canal. If at this time the lock is cracked to allow only a very slight flow of water, fish can be observed concentrated at this crack and passing through it back into the lake.

It has also been observed that when the canals are draining into the lake fish will leave the rim canal and the shore waters of the lake. During these times fish may be caught in the middle of the lake but not around the edge where the contaminated water of high oxygen demand is entering.

Studies of ground water indicate that it is very low in dissolved oxygen and high in oxygen demand but not as high in H_2S as some of the canal water samples. This brought up the question of where the H_2S was coming from. Some could be accounted for by the action of anaerobic bacteria in the soil; however, it was hard to see how such a concentration as 30 p.p.m. could be developed. Quite by accident in the course of a soils experiment it was discovered that when muck soil ash is mixed with raw muck soil and water a considerable quantity of H_2S is liberated. This led to the conclusion that when muck soil burns sulfides are formed due to the limited oxygen supply. Further investigations showed that ash from very old muck fires when mixed with a little acid would not liberate H_2S; however, relatively new ash would. The action of water leaching through this ash can account for the occasional occurrence of high levels of H_2S in the canal water. The slow decomposition of the muck soil will account for the low dissolved oxygen of the soil water.

On October 9, 1946, a test was made of the H_2S content of

TABLE 1

HYDROGEN SULFIDE CONTENT OF THE CANAL BORDERING THE REAR OF THE EVERGLADES EXPERIMENT STATION

Date 1946	Notes	ppm H_2S
September 30	Shortly after a heavy rain	40
October 1	With no further rain	18
October 2	With no further rain	15
October 4	With no further rain	2
October 8	After rain of October 7	29

the water in the rim canal that encircles Lake Okeechobee. It was found to be 7.2 p.p.m.

CONCLUSIONS

(1) The water under live hyacinth mats is not suited for normal fish life except where rapid flow from a good water source will maintain the necessary water quality.

(2) During the summer months the canal water will become toxic to fish even in open surfaces.

(3) The toxicity of the water is caused by the action of water on muck soil and is due to low levels of dissolved oxygen, high oxygen demand, and the presence of other toxic substances such as H_2S.

(4) The action of decaying hyacinths during the summer months will not cause fish kill as normally there will be no fish, which would be affected by their decomposition, under these hyacinths. That is to say, the condition of the water at times is so unsuitable for fish life that the decaying hyacinths could not make it worse.

DISCUSSION

Led By

LAMAR JOHNSON*

and

B. A. BOURNE**

The discussion was initiated by Mr. Lamar Johnson, Chief Engineer, Everglades Drainage District, with a statement in reference to the report that had recently been prepared by the District to cover two years of hyacinth eradication work on the arterial canal system of the Everglades District. This report is to be found in full in the Appendix of this volume of the Proceedings beginning on Page 149.

Many questions were raised regarding the details of hyacinth and other water weed control which were largely answered in the several papers already presented in the symposium. On this account the discussion pertaining thereto will not be repeated here.

More discussion was raised in regard to the control of Para grass on ditch banks, and particularly where it extends into ditches or out into the water area from the banks of larger canals, than on any other subject. It was generally agreed that this is one of our most difficult pests to control, and reference was made to the work of Mr. B. E. Lawton, County Agent in Broward County, where a considerable degree of success has been achieved with the use of sodium chlorate on the mineral soils of that section of the Everglades.

In commenting on the work with sodium chlorate, Mr. Charles C. Seale called attention to the very considerable danger of fire with this compound. Whereas good results have been reported on mineral soils through the use of 160 pounds of chlorate per acre, very poor results were obtained on muck soils through the use of this and even greater amounts. Mr. Seale also reported in a very preliminary way on the use of ammonium trichloracetate on this pest by stating that he had been able to kill the rootstock with applications varying from 100 to 200 pounds of the chemical per acre depending to some extent on soil conditions. He also reported that very little work had been done to date with this chemical where the Para grass had passed out onto the water surface of larger canals from its rooted position on the bank.

Dr. B. A. Bourne, of the U. S. Sugar Corporation, Clewiston, raised the all important question of cost by citing the fact that treatment of a mile of canal 32 feet wide with 175 gallons of

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**Vice President—Research, U. S. Sugar Corporation, Clewiston, Florida.

benechlor cost $400.00, while that for a 16 foot canal infested with nigger wool was $115.00 per mile. Lamar Johnson called attention to the fact that the Everglades District's costs were all in the report referred to above and which is to be found in the Appendix of this volume, Pages 149-159.

Dr. Bourne also called attention to the relation of weed population in the canals and farm ditches to rate of silting, and called attention to the fact that this alone would justify the weed control operation. Attention also was called to the economy of mopping up operations following the first kill in contrast to allowing practically full recurrence and thus necessitating the cost of the full treatment again.

With reference to the cost of treatment, Mr. L. S. Evans brought much encouragement into the discussion by calling attention to the fact that, while some of the newer napthas that are proving so effective against water weeds are required in about the same amount as the benoclor compounds, the cost at the present time, still at a preliminary level, is only a fraction of the latter, i.e. about 20c per gallon against $3.00 to $3.50 per gallon. Mr. C. H. Anderson, of Esso Oil Company, New York, stated that until we know exactly what naptha formulations are best to use, more about freight rates and have some idea of the volume needed in various sections of the country, an appreciable amount of uncertainty in the price shall doubtless continue.

Dr. Bourne closed the discussion by advising that he had no further comment and with the remark that "we are a lot wiser than we were before the meeting."

SYMPOSIUM II.

THE OVERALL WATER CONTROL PROGRAM FOR SOUTH FLORIDA

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A BRIEF REVIEW OF THE WATER CONTROL PROGRAM AS IT HAS DEVELOPED DURING THE PAST SIX YEARS

LAMAR JOHNSON*

Reclamation of the Florida Everglades may be divided into three periods. First, the period from 1907 to 1931 during which time the present canal system was constructed and reclamation evolved from a visionary dream to a tangible actuality. Second, the period from 1931 to 1942 when Everglades Drainage District, the agency charged with the responsibility of reclaiming the Everglades, wallowed in the doldrums of debt and litigation and all improvement and maintenance of the arterial canal system stopped. However, it was during this period that the levee around Lake Okeechobee was built, an item that contributed much to the present extent of development by subdrainage districts and private interests. Third, the period from 1942 to the present, during which general recognition was given to the multiple problems other than drainage and efforts were directed toward the development of a plan of water control that would insure maximum utilization of both soil and water.

The first formal recognition of the need of such a plan was expressed in a resolution of the Soil Science Society of Florida in meeting in West Palm Beach, Florida, on April 21, 1942. At its meeting the following year, in Belle Glade, Florida, the Society adopted a resolution urging Everglades Drainage District to assume responsibility for an over-all policy and plan and to coordinate the activities of all governmental agencies in the execution of such plan.

These resolutions were timely. Two Federal agencies, the Soil Conservation Service of the Department of Agriculture and the U. S. Geological Survey of the Department of Interior, were then engaged in programs of investigations and surveys in the Everglades area. The program of the Soil Conservation Service, conducted in cooperation with the University of Florida, Agricultural Experiment Station, included a soil survey of the Everglades and recommendations for water control. The program of the U. S. Geological Survey included both surface and sub-surface investigations and was conducted in cooperation with Dade County and Everglades Drainage District. The work of these two Federal Agencies during this period supplied the basic facts upon which a plan of general water control could be developed.

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The resolutions of the Soil Science Society were timely in that for the first time in many years Everglades Drainage District, having quieted its financial troubles, was free to consider its physical works and the requirements of the landowners. It was obvious that the first responsibility of the District was to determine the future policy and plan for the conservation and development of the land and water resources of the Everglades. About a week after the Soil Science Society meeting in Belle Glade, the Board of Commissioners of Everglades Drainage District, at a public meeting held in Miami on March 26, 1943, arranged a meeting in Tallahassee, Florida, on the date of April 14, 1943.

This meeting was attended by State officials and representatives of State and Federal agencies engaged in Everglades reclamation and its problems. The meeting resulted in agreement on the need for a comprehensive plan to prevent the waste of soil and water resources, and agreement that Everglades Drainage District serve as the authority in the preparation and execution of such a plan and program.

As the first step in determining the future policy and plan for water control in the Everglades, the Board of Commissioners of Everglades Drainage District, on August 13, 1943, authorized the organization of an Advisory Committee comprised of sixteen persons recognized as authorities in various problems of the Everglades. The work of this Committee resulted in a published report dated May 1, 1944.

This Committee's report recognized the fact that not all peat soils in the 'Glades were suitable for agricultural development. It stressed the fact that the present canal system, even if completed to designed cross-section, was inadequate to serve even the reduced area of potentially agricultural soils. For the first time a report of this kind recommended developing large areas of Everglades wild lands for conservation purposes. While pointing the way toward the development of a plan of water control, finances were not available to prepare a detailed plan for the Everglades.

Early in 1945, Everglades Drainage District released a report prepared by W. Turner Wallis, then Engineer for the district. This report briefly recommended certain improvements to the water control system, estimated the cost of such improvements and discussed financing under existing legislative authority. In response to notice of hearings before the U. S. Engineers, in Belle Glade, Florida, in April, 1946 and in June, 1947, the District submitted reports making specific recommendations for the improvement of the major canal system of the Everglades. These latter reports were complete with regard to size and quantities of the items of construction recommended and as to their operation after construction under conditions of both drainage and irrigation.

In 1945, the Soil Conservation Service of the United States

Department of Agriculture, working in cooperation with the University of Florida, Agricultural Experiment Station, released an interim report on soils and water control in the Everglades Drainage District. This report was released in printed form, including accompanying maps, in March, 1948.

These plans of improvement recommended by Everglades Drainage District and the Soil Conservation Service are very similar, reflecting the close coordination of effort in analyzing the data assembled in previous years of research and survey, and in the recommendations for a feasible solution of the many problems. Many of the recommendations of these reports are now recognized as being basic to the protection and development of southeast Florida of the future.

As a result of the many hearings and conferences during 1946 and 1947, the District Office of the U. S. Engineers in Jacksonville, Florida, began the preparation of a comprehensive report on flood and water control for the Everglades and southeast coastal areas. Given impetus by the disastrous flood of 1947, the report was completed during that year and its scope enlarged to include the Kissimmee and St. John's valleys. This report was considered by Congress during its 1948 session and the first phase involving expenditures of $70,000,000 was approved and appropriation of $16,300,000 authorized. Later, Mr. Harold Scott will give you the details of this plan.

For years Florida has wasted soil and water resources with the reckless abandon of the pioneer, without plan or purpose for the future. Today we have a Federal approved plan covering one-fifth of the State's area. The purposeful attitude of the people was evident at the hearings before the U. S. Engineers and before the Congressional committees. We know that Florida is blessed with abundant rainfall and arable soils which if utilized to their fullest extent will assure its future as an agricultural state. At last we are beginning to realize the true value of these resources. We have come a long way in the last six years.

SOME IMPORTANT GEOLOGIC PROBLEMS TO BE ENCOUNTERED IN THE DEVELOPMENT OF A FULLY EFFECTIVE WATER CONTROL PROGRAM FOR SOUTH FLORIDA

NEVIN D. HOY*

Inasmuch as no formal manuscript has been provided to cover the above subject, it will be reported only very briefly in the usual manner.

In preparation for the interesting and informative discussion which Mr. Hoy gave on the relationship between the geology of the area and an effective water control program for South Florida as it shall have to be recognized and worked with from the engineering standpoint, numerous rock samples, maps and a complete geologic cross section extending from Ocala to Florida City were brought into view.

With the geologic cross section showing the inter-relationship of the natural formations of rock, each with the other, and actual samples of Miami Oolite and Tamiami limestone as background material, Mr. Hoy emphasized and reemphasized in about every possible way the very great importance of giving the fullest possible consideration to the extremely high porosity of such substrate materials in relation to any impoundings of surface waters that are to be made over them—at least made in a theoretical way— for the porosity of rocks such as these is said to approximate that of washed gravel.

A map also was shown which outlined the location and extent of the marl, muck and other surface and sub-surface conditions. Attention also was called to the fact that water passes through marl very slowly and that the Fort Thompson formation, which is largely the foundation rock of the Upper Glades, has a comparatively low permeability. In contrast, the Anastasia and Miami Oolite formations both have a very high permeability, whereas Tamiami rock was said to be the most permeable known.

The close relationship of these geologic conditions in South Florida to the problems of water control, soil conservation and salt water intrusion in relation to the safety of the domestic water supply was clearly shown in every respect and left little room for doubt as to the seriousness of the engineering problems that are created by natural geologic conditions to be found in the sub-surface conditions of South Florida's geologic setup. We can find no particular comfort furthermore, in the knowledge that each day, in nature's own, slow way, these conditions are getting worse rather than improving.

In view of the fact that a considerable amount of the infor-

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mation reviewed by Mr. Hoy has been published in earlier volumes of the Proceedings of the Society any reader who is interested to that extent is respectfully referred to the following items: (1) Evans and Allison (Soils of the Everglades), Vol. IV-A, pp. 34-46 (1942); (2) Parker (Geology and groundwater conditions), Vol IV-A, pp. 47-76 (1942); (3) Ferguson (Surface water studies), Vol. IV-A, pp. 77-85, (1942); (4) Ferguson (Surface water studies), Vol. V-A, pp. 18-23, (1943); (5) Parker, Hoy and Stevens (Geological studies), pp. 33-94, (1943); (6) Gallatin and Henderson (Progress of soil survey), Vol. V-A, pp. 95-104, (1943); (7) Bogart (Surface water relationships), Vol. VIII, pp. 60-71, (1946-7); (8) Parker (Municipal water supply), pp. 72-88, (1946-7).

As among the above references, Figures 6 and 7, pages 69 and 70 of Proceedings Volume V-A, are of particular interest in showing the extremely porous nature of the supporting limerock in the lower reaches of the Everglades, a point that has come up repeatedly in the discussion of the hydrologic problems of that area. It is obviously one that must be given more and more careful consideration in working out the details of the overall plan of water control for South Florida if it is to serve that area effectively in the future. At least that is the emphases that Mr. Hoy seemed to give it in the course of his review of the subject. —*Editor.*

THE CENTRAL AND SOUTHERN FLORIDA PROJECT

HAROLD A. SCOTT

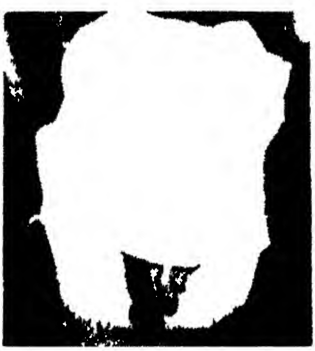
The people of Florida have within their grasp the greatest single achievement since the establishment of statehood, namely, the Comprehensive Plan of Improvement for Central and Southern Florida. This plan when completed will relieve large areas from the ravages of floods and droughts and bring untold benefits.

HAROLD A. SCOTT

I would like to briefly describe the main features of the plan for the benefit of the few who may not be familiar with it.

General area.—Flood control and water control improvements are proposed in central and southern Florida south of a line extending from the east coast through Lake Harney and Orlando, and along the westerly limits of the Kissimmee River basin as shown on Figure 1.

The area has been divided in-



MALBEE RUSSELL SCOTT

Ed. Note: Following the close of the meetings in Clewiston on Saturday, Oct. 13th, shortly after noon, it became known that while Mr. Scott was in attendance upon them his wife had gone to the hospital in Jacksonville to await the arrival of the big bird with the long legs and a great deal of knowhow. Up to the time he left Clewiston early afternoon there had been no further news nor was there any by the time he had arrived at Reservation Headquarters, St. Lucie Locks. However, by the time he arrived in Stuart a long distance telephone call revealed that a son had "weighed in" at 3:07 P.M., tipping the beam at 7 pounds, 7 and 1/3 ounces; and that is the reason Malbee Russell Scott is tucked away down in the corner—so his dad can keep an eye on him from here on out; and perhaps recall, betimes, how difficult it was to keep his mind on soil and water conservation, unified plans and all that sort down in the Everglades when his mind and heart so definitely were in Jacksonville at such a time.

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[1]—Head, Multiple Purpose Report Section, Corps of Engineers, Jacksonville. Fla.

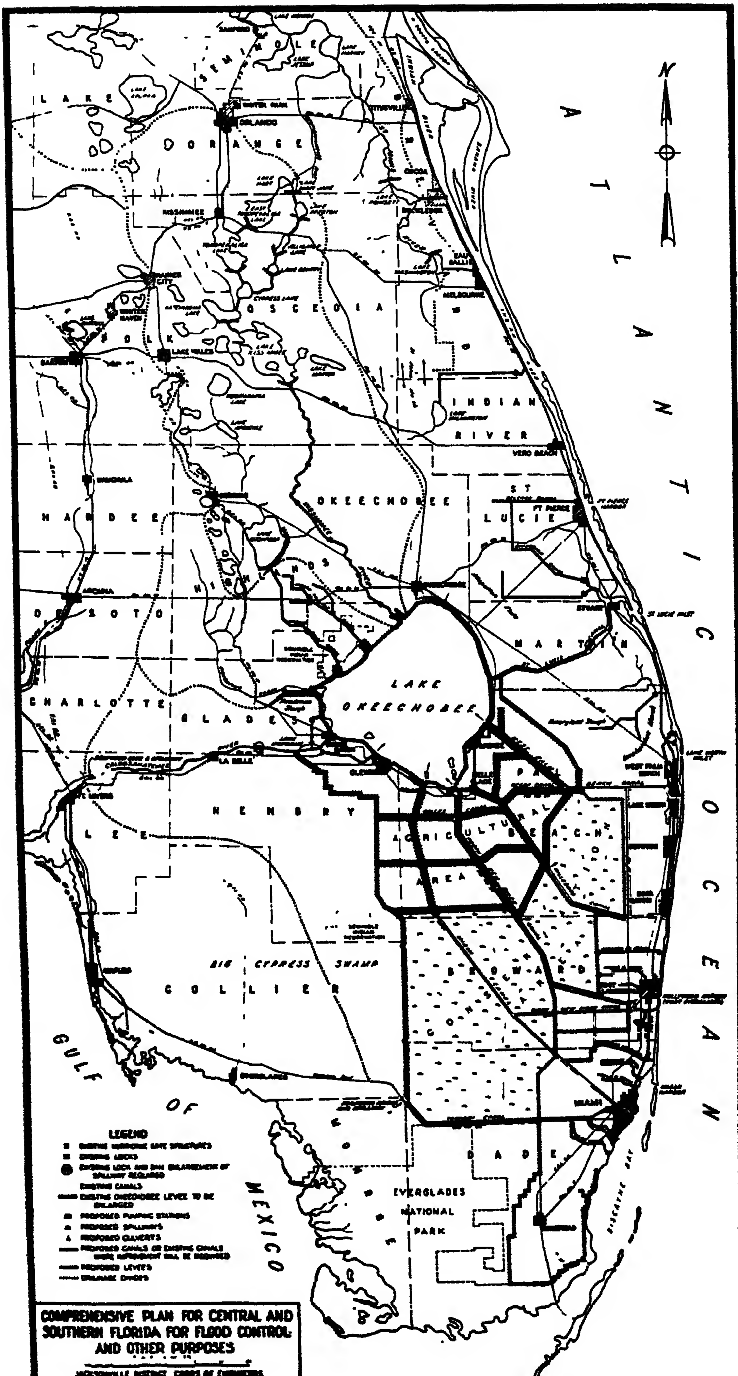

ATLANTIC OCEAN
GULF OF MEXICO
N
LAKE
SEMINOLE
ORANGE
OSCEOLA
POLK
INDIAN RIVER
HARDEE
OKEECHOBEE
ST LUCIE
HIGHLANDS
DE SOTO
MARTIN
CHARLOTTE
GLADES
LAKE OKEECHOBEE
HENDRY
PALM BEACH
LEE
AGRICULTURAL AREA
BROWARD
CONSERVATION
BIG CYPRESS SWAMP
COLLIER
MONROE
DADE
EVERGLADES NATIONAL PARK
ORLANDO
MIAMI
LA BELLE
LEGEND
COMPREHENSIVE PLAN FOR CENTRAL AND SOUTHERN FLORIDA FOR FLOOD CONTROL AND OTHER PURPOSES
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS

Figure 1.

to four more or less natural basins for study. The St. Johns River basin includes the area from Lake Harney south to the north Martin County line. The Kissimmee River basin area also includes the Fisheating Creek basin. The Lake Okeechobee-Everglades area includes Lake Okeechobee, the St. Lucie Canal, and Caloosahatchee Canal and River, and about 1,000 square miles of rich agricultural area south and east of the lake. The east coast area includes the coastal ridge in Palm Beach, Broward, and Dade Counties, and about 1,500 square miles of Everglades set aside for water-conservation purposes.

St. Johns River basin.—Any change in the regimen of flow of the St. Johns River must necessarily have varied effects on the surrounding areas which could be made beneficial by careful study, and which also could be detrimental if carelessly undertaken. The rich Indian River fruit area lying along the Indian River derives its water supply and a goodly share of frost protection from the St. Johns River marshes. Overdrainage of this marsh area would not only affect these valuable considerations, but also the water supplies of the towns along Indian River; therefore, the plan of improvement proposes to maintain these marsh areas at their present limits by providing levees at the northerly outlets of Lake Poinsett and Lake Washington, thereby making use of the natural reservoirs provided by nature. The plan proposes to provide canals from Lake Poinsett, Lake Washington, and Lake Wilmington to Indian River for the discharge only of excess flood waters, thereby reducing the amount and duration of flooding now experienced on the agricultural and pasture lands in this area. These canals would be provided with control structures at the lower end consisting of Tainter gates and a concrete structure. In the same manner, canals would be improved or provided in St. Lucie County to provide relief in the upper marshes from excess flood waters. These canals would consist of Belcher, Diversion and a third canal along the county line between St. Lucie and Martin. These canals would also be provided with adequate spillway and control works.

The Kissimmee River basin.—The Kissimmee River basin and its headwater lakes, including those on the low indeterminate divide between the St. Johns and Kissimmee Rivers, have an area of about 4,400 square miles. This includes the area of the series of lakes north of Lake Istokpoga, Indian Prairie Canal, Fisheating Creek, and Taylor Creek, all of which drain from the north or northwest into Lake Okeechobee. All of the lakes in this basin have a potential use as reservoirs for storage of water during the rainy season to be discharged over the dry season; however, some means must be provided for the disposal of excess flood waters. The most feasible method is by enlarging the existing connecting canals and the Kissimmee River. Any improvement of the Kissimmee River however, must be so planned as to avoid overdrainage of the area between Lake Kissim-

mee and Lake Okeechobee in dry periods. The Comprehensive Plan proposes to provide low levees at the outlets of these natural lakes, with adequate control works for regulation purposes. The Kissimmee River itself would be improved and provided with six low dams with control works across the valley, resulting in a continuous reservoir system between Lake Kissimmee and Lake Okeechobee. The lake and reservoir would permit the retention of water by storage after the flood excess has been discharged. This storage would then be available to increase low water flow during dry seasons. The Indian Prairie area would have existing canals improved and extended to Lake Istokpoga with works to discharge excess flood waters more rapidly, while also maintaining adequate ground water during drought seasons. Fisheating Creek would be provided with an improved canal in the lower basin and a spillway for diversion purposes to reduce the amount of local flooding.

Lake Okeechobee-Everglades area.—a. *Lake Okeechobee.*—In its present status and as considered under the Comprehensive Plan of Improvement, Lake Okeechobee is a multiple-use reservoir with flood control, navigation, and water conservation functions. Its waters are impounded by the present levee system and a measure of control is provided by the existing St. Lucie Canal and improved Caloosahatchee River. The existing levees around the rim of Lake Okeechobee protect seven towns and over 130,000 acres of developed rich agricultural land from direct overflow from the lake. The outlet canals and the lake provide a navigable waterway across Florida. Between elevations of 12.56 and 15.56 feet above mean sea level (the present prescribed limits of regulation) the lake provides storage of 1,320,000 acre-feet of water. This great reservoir and its controls are the heart of any plan for flood control and water conservation in south Florida.

b. *Levees.*—The existing levees around the perimeter of Lake Okeechobee were designed to withstand a hurricane attack even more severe than that of 1928. They served their intended purpose in 1945 and 1947 by withstanding hurricane-driven tides and waves with relatively minor damage and with no danger of over-topping or breaching. Experience gained as a result of the floods and winds of 1947 indicates, however, that if the Comprehensive Plan be adopted, a low levee should be extended around the lake shore from the St. Lucie Canal northward to tie in with the present north shore levee, to protect the development which has taken place in that area since the existing levee project was built. Also, a low levee should be provided along the northwestern shore of the lake from the Kissimmee River to Fisheating Creek to protect pasture lands of the Indian Prairie section from overflow by normal rises and wind tides on the lake. This limited protection along the northwestern shore is adequate for present protection of this area, which is pasture land without urban development. In addition to these extensions,

some modification of existing levees may be found desirable in the light of experience gained during the 1947 storm.

c. *Completion of navigation improvement.*—The authorized 8-foot navigation channel from Stuart to Fort Myers has not yet been provided. At present it is only 6 feet. Enlargement of the St. Lucie Canal and Caloosahatchee River for lake control and modifications of the levee systems for Lake Okeechobee, would result in deepening existing channels for lake-control purposes. This would incidentally provide depths of 8 feet or more in the waterway across Florida and would substantially complete that authorized project. Deepening of the channel in the Caloosahatchee River without control works at its seaward end would aggravate salt-water intrusion and overdrainage during droughts, which are already serious problems in this area. To prevent this, the plan provides for construction of a new lock and spillway on the Caloosahatchee River above Fort Myers.

d. *Everglades area.*—The plan would provide flood protection and water control for 1,027 square miles of developed and potentially productive agricultural land adjoining the southern shore of Lake Okeechobee. Flood protection would be provided by constructing levees around the area and by joining them to the existing Lake Okeechobee levee (figure 2). Water control would be accomplished by the construction of a canal network connected to 8 pumping stations on the perimeter of the system. The network would be formed by improving existing canals within the area and by constructing interconnecting and rim canals. The pumps would dispose of excess run-off within the area by pumping from the canal network either into the lake, or into the conservation area to the south, or both; and would also pump water into the area from Lake Okeechobee when needed during dry seasons. The system would also permit a flood discharge of 7,000 cfs from Lake Okeechobee to the conservation area for aiding the control of Lake Okeechobee. Conservation would be provided by pumping excess run-off from the area into the conservation area.

East coast area.—This area consists of the coastal-ridge section and the eastern portions of the Everglades extending from the north Palm Beach County line to the southern tip of Florida (Figure 2).

a. *Everglades conservation area.*—The plan would create three interconnected reservoir areas totaling about 1,500 square miles which would occupy portions of Dade, Broward, and Palm Beach Counties, and which have been shown by the Soil Conservation Service to be unsuited to agricultural development. The reservoirs would be created by constructing a system of levees from the West Palm Beach Canal southward between the main body of the Everglades and the west edge of the coastal ridge to the Tamiami Trail, westward on the trail to the Collier County line, then northward to tie into the west rim levee of the Everglades agricultural area. Levees along the Hillsboro and

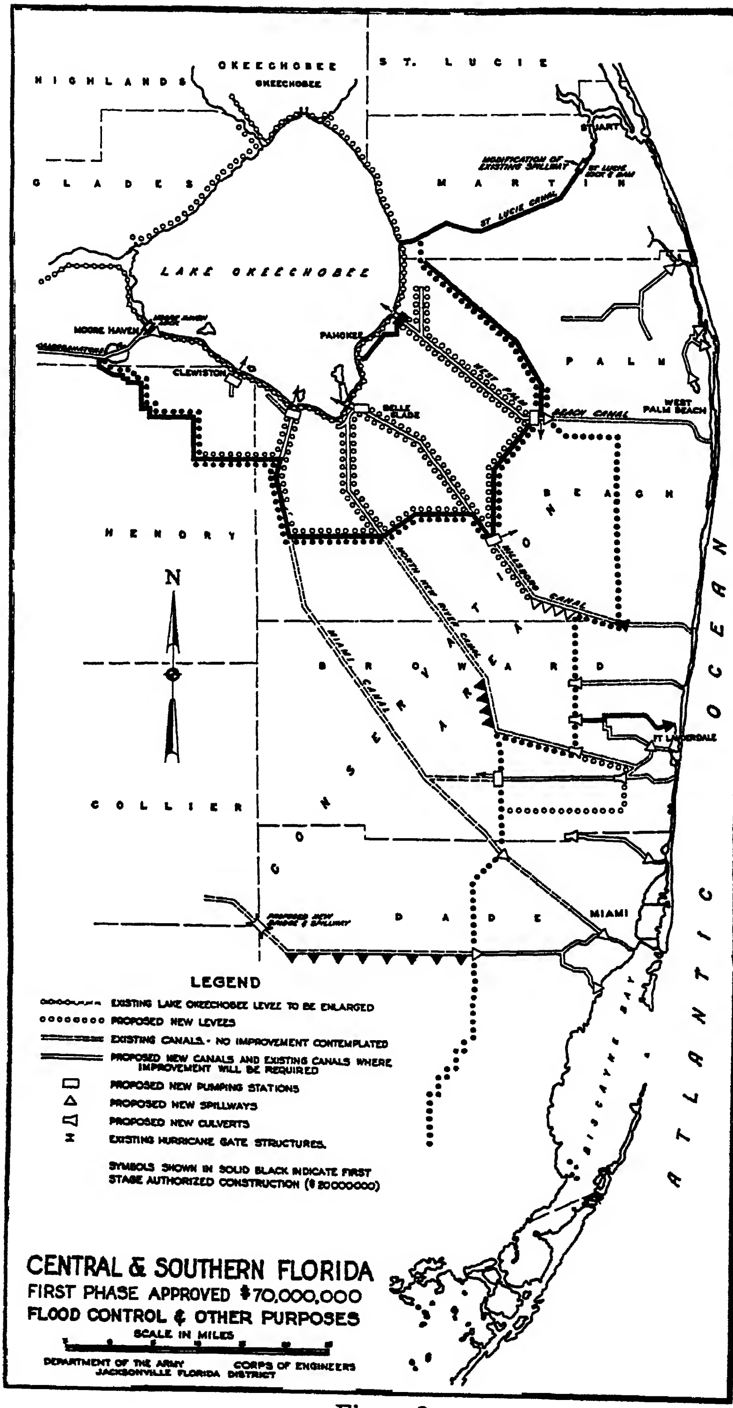

HIGHLANDS
OKEECHOBEE
OKEECHOBEE
ST. LUCIE
GLADES
MARTIN
STUART
LAKE OKEECHOBEE
MOORE HAVEN
PAHOKEE
CLEWISTON
BELLE GLADE
PALM
BEACH
WEST PALM BEACH
HENDRY
BROWARD
COLLIER
DADE
MIAMI
FT LAUDERDALE
ATLANTIC OCEAN
N
LEGEND
EXISTING LAKE OKEECHOBEE LEVEE TO BE ENLARGED
PROPOSED NEW LEVEES
EXISTING CANALS - NO IMPROVEMENT CONTEMPLATED
PROPOSED NEW CANALS AND EXISTING CANALS WHERE IMPROVEMENT WILL BE REQUIRED
PROPOSED NEW PUMPING STATIONS
PROPOSED NEW SPILLWAYS
PROPOSED NEW CULVERTS
EXISTING HURRICANE GATE STRUCTURES.
SYMBOLS SHOWN IN SOLID BLACK INDICATE FIRST STAGE AUTHORIZED CONSTRUCTION ($20000000)
CENTRAL & SOUTHERN FLORIDA
FIRST PHASE APPROVED $70,000,000
FLOOD CONTROL & OTHER PURPOSES
SCALE IN MILES
DEPARTMENT OF THE ARMY CORPS OF ENGINEERS
JACKSONVILLE FLORIDA DISTRICT

Figure 2.

North New River Canals would divide the conservation reservoir into three parts, interconnected by gated spillways through the levees. These reservoirs would store the maximum-record rainfall on the conservation area plus the run-offs from the area north of West Palm Beach Canal, the Everglades agricultural area, and some flood discharge from Lake Okeechobee. Impoundment of these waters would prevent their flowing eastward as heretofore and flooding the developed areas along the coastal ridge. Maintenance of water in the conservation area would provide water for use on the east-coast agricultural lands when needed, raise the ground-water table, and replenish water supply for the east coast communities, ameliorate salt-water intrusion in the east coast water supply well fields and streams, and benefit fish and wildlife in the Everglades.

Gated spillways in the Tamiami Trail levee would permit discharge of excess water from the conservation area onto low-lying areas to the south, and thence to the lower end of the peninsula. The part of the east coast protection levee which forms the eastern boundary of the conservation area is the major feature for protection of the east coast.

b. *Palm Beach County.*—The planned improvements in Palm Beach County serve various purposes. Flood relief and water control for the Hungryland and Loxahatchee Sloughs would be provided by constructing a canal to the coast with a control structure near its outlet. Flood discharge from Lake Mangonia would be diverted by a canal to Lake Worth. Water control for the Lake Osborne area would be provided by a control at the outlet of the channel at the West Palm Beach Canal, and by a short canal from Lake Osborne to Lake Worth with a control structure at its outlet to prevent salt-water intrusion. Lake Ida would be benefited similarly by a short canal and control structure. Construction of spillways in the conservation levees at the West Palm Beach and Hillsboro Canals would provide water to the entire area when needed during drought periods.

c. *Broward County.*—The plan for improvements in Broward County provides for flood relief, water control, and alleviation of salt-water intrusion. These would be secured by improving and extending the existing Cypress Creek, Middle River, Plantation Road, and Hollywood Canals, and by placing control structures in those canals. Culverts and spillways in the conservation area levees to the west would bring water from the conservation reservoirs to this area by way of Cypress Creek, Middle River, Plantation Road, North New River, and Dania Cut-off Canals for use during dry seasons and for preventing salt-water intrusion.

d. *Davie agricultural area.*—The plan would provide for flood protection and water control for an area of approximately 105 square miles of developed and potentially productive agricultural land west of Dania along the South New River Canal. Flood protection would be provided by constructing and improv-

ing levees around the area; these would be connected to the Broward County conservation area levee on the west. Water control would be provided by improving the South New River Canal and constructing a pumping station at the conservation area levee. The pump would discharge excess water from the Davie area into the conservation area or draw therefrom for use during dry periods. A gated culvert in the canal at State Road 7 would permit flow for water supply and salt-water control in the Dania Cut-off Canal and along the coast.

e. *Dade County.*—The plan of improvement for Dade County would provide for flood control and protection, water control, and alleviation of salt-water encroachment. These benefits would be secured by improving the channels, and constructing control structures at the outlets of the following existing canals:

Miami (in part)	Snake Creek	Coral Gables
Comfort	Biscayne	Snapper Creek
Tamiami	Little River	Black Creek

Gated culverts at the head of Snake Creek, Miami, and Tamiami Canals would provide for the flow of water from the Everglades conservation reservoirs into the area for use during dry seasons. The levee (some 74 miles long) surrounding the agricultural lands of the Perrine-Homestead area would protect against overflow of flood waters from the Everglades and against ocean tides driven by hurricanes from the south and east. Salt barrier-type spillways and gated culverts—13 in all—in the east and south walls of this levee would control the discharge from the canals and prevent salt-water intrusion.

Division of cost.—The total cost of the proposed comprehensive improvement has been divided between the Federal Government and local interests based upon the proportion of benefits to accrue to flood control, navigation, and preservation of fish and wildlife, and benefits from increased use of land. Therefore, it has been deemed appropriate that the Federal Government should pay 85 percent of the total cost of the project, and local interests 15 percent of the project plus the cost of lands and relocations. This breaks down into the Federal share of the construction cost amounting to about $171,041,000 and $749,000 annually for maintenance and operation. Local interests would pay $29,162,000 plus the cost of lands and relocations estimated at $7,942,000 and an annual maintenance cost of $3,034,000.

Construction program.—The Comprehensive Plan is a long-range plan for the control and use of water resources of most of central and southern Florida. It should be initiated at the earliest possible date, as the need for flood protection, water control, and conservation of water is urgent. Now that the plan is approved in part by Congress, future progress in its accomplishment will depend equally on Congressional appropriations for planning and construction and on prompt action by local interests in providing the cooperation required of them.

Assuming, however, that adequate appropriations were made by Congress and that requirements of local cooperation were met, the entire comprehensive development could be completed under an orderly and efficient construction program in 10 years. It is considered, however, that completion of certain parts of the plan should be deferred beyond this period, as the need for such features will depend on progressive development of the areas.

All features set up as parts of the Comprehensive Plan are considered necessary and economically justified. It is practicable now to establish definite priorities for planning of individual items. Some parts of the plan, such as those required for protection of human life and of existing highly developed urban and agricultural areas, are obviously more urgently needed than the longer-range features of the plan. In addition, engineering considerations will require an order of development which would produce, step-by-step, construction of the works which can be operated from the beginning with the greatest efficiency, and which would obtain progressively, from the beginning, the benefits which the plan is designed to produce. The features of the plan are of course subject to some modification of details to make them conform as nearly as practicable to the desires of local interests and to the needs of each particular case.

Conclusions.—The problems of flood control, drainage, and water use in central and southern Florida are complex. They range from protection of life and property from hurricane-driven tides at Lake Okeechobee to maintenance of water levels in dry periods to combat the burning and destruction of muck lands of the Everglades and to maintain the ground-water supply in the lower east coast area. The Comprehensive Plan has been prepared after full consideration of these varied problems. Its preparation has been greatly facilitated by information and requirements furnished by other Federal agencies and by the full cooperation of the local agencies and individuals. The Comprehensive Plan is not a panacea for all the difficulties inherent in the development of this region. No feasible plan of improvement within the realm of economic justification could completely banish flooding of this area, or insure that all needed water supplies would be available during the dryest periods. However, when completed the development would provide a high degree of flood protection and conservation of the water resources of the region. A long-range plan of this kind for flood protection and water control is urgently needed now, so that development of the region can proceed in an orderly manner which will preserve its resources of water and land for future generations. Analysis of economics shows that the project as a whole is justified by a wide margin. Construction and subsequent operation of the comprehensive development to insure that its purposes are obtained would require the best efforts and continued cooperation of Federal, State, and local agencies, but the interest shown

in this plan by the State of Florida and local interests indicates that this can be accomplished.

I know that you are primarily interested in the present status of the comprehensive flood-control project. On June 30, 1948 Congress authorized a flood-control bill containing the following item:

> "The project for Caloosahatchee River and Lake Okeechobee drainage areas, Florida, authorized by the River and Harbor Act of July 3, 1930, as amended, is hereby modified and expanded to include the first phase of the comprehensive plan for flood control and other purposes in central and southern Florida as recommended by the Chief of Engineers in House Document Numbered 643, Eightieth Congress, subject to the conditions of local cooperation prescribed therein, and there is hereby authorized to be appropriated the sum of $16,300,000 for partial accomplishment of said plan."

The first phase referred to in the item refers to work estimated to cost $70,000,000 and covers the area shown on the map. However, as noted in the item, Congress authorized only $16,300,000 which will be supplemented by an additional 15 percent making a total sum of about $20,000,000 available for construction purposes. This work is shown in black on the map of Figure 2.

It is anticipated that Congress will appropriate a small part of the $16,300,000 so that it will become available for advance planning and some construction during the fiscal year 1950. At the present time no funds have been appropriated by the Federal Government to initiate any work on the plan. Prominent local interests, realizing that a year must pass before any work could be initiated, have taken steps to obtain funds for the Corps of Engineers for advance planning work until Federal funds become available. The Corps of Engineers has received a contribution from local interests of $75,000 and an additional $45,000 will be furnished in the immediate future. This advance of money is the first part of local cooperation out of a total of almost $3,000,000 which must be advanced before the Federal Government will begin construction on the first phase of the plan. This money has enabled the Corps of Engineers to initiate field surveys and office studies. Traverse and topographic surveys are in progress in Palm Beach, Broward, and Dade Counties. Core boring will be started within the next few weeks.

It is not known definitely as to how local interests will obtain the full amount of local cooperation necessary to put the plan into effect. Many local interests have discussed various means of how this money might be obtained. The Federal Government considers that it is a problem which must be solved by local interests. No doubt many of you in this room will be called upon to offer services and advice on the various means of making the payment of $3,000,000. Discussions have been had relative to obtaining the money by local taxes, or by the State assuming the

entire burden. It must be realized that while this plan appears to be local, the benefits are State-wide and, in many instances, Nation-wide.

During the planning and construction of the Comprehensive Plan, many difficulties will arise in procuring rights-of-way and spoil areas, and determining the lands which should be used for conservation areas and which lands should be reserved for agricultural endeavors. Many of these difficulties will be settled only after many discussions, arbitration, and some will doubtless find their way into the courts of the State of Florida. Already the District Office in Jacksonville of the Corps of Engineers has received numerous requests for moving the levee locations, canal locations, excluding this land and that land, and taken all together generally rehashing the general alignment of the main features of the plan. These requests have all been answered with the statement that consideration will be given to minor adjustments in the alignments of the various features but the plan as previously conceived is being adhered to.

It is firmly believed that every problem which will arise in connection with the plan can be worked out to a satisfactory conclusion with the help of local interests who own the lands and are directly affected by the project. The most important consideration is that the Comprehensive Plan which was only a dream yesterday is a real and living project today. The Corps of Engineers stands ready to complete the project as rapidly as funds become available so that floods like those of 1947 and 1948 will become only a memory.

OUTSTANDING BENEFITS TO BE DERIVED FROM THE DEVELOPMENT OF A COMPREHENSIVE WATER CONTROL PROGRAM FOR SOUTH FLORIDA

J. E. BEARDSLEY[1]

The first and, by far, the most outstanding fact to be observed in connection with present efforts at developing a broad, overall water conservation and control program for South Florida is that, for the first time in the history of Everglades development, we have a really effective unanimity of opinion among all interests throughout the area.

I have been here taking it in for 34 years and it is the first time in all of my experience that as many as 3 or 4 have gotten together and, in substance, agreed "Here is something." Granted that the plan may have defects at the present time which, as Mr. Scott has pointed out, are being hashed over from time to time to eliminate at least some of the errors or miscalculations in the original planning, nevertheless, for the first time we have something on which we can agree. Some of you may recall that at the last session of the State Legislature there was quite a unified and agressive effort to abolish the one agency which, in the past, had been attempting to deal, at least in a portion of the territory under discussion (South Florida), with the problem of water control. Reference is to the Board of Commissioners of the Everglades Drainage District.

Now, backed by a combination of powerful circumstances (peak flood conditions), we have an excellent example of what can be done by comprehensive planning in the prevention of such destructive situations. The two needs, prior planning and the prevention of such catastrophic experiences as we have so recently passed through, are now firmly bound together in the public mind and recognition is finally being given throughout the State to the merit of the long time contention that has been argued so strongly in South Florida for many, many years in behalf of a safe and sound overall water control program.

We hope the next session of the Legislature will show recognition of the facts which exist and a willingness to give financial support to the necessary phases of the comprehensive plan. We have recognition even in Washington that the program should be handled as a national as well as a local problem. As the best possible evidence of that fact we have the Chairman of the Subcommittee of the Senate which deals with matters of this nature arriving in the State very shortly for a personal examination of this area and its problems.

[1]—Member, Board of Commissioners, Everglades Drainage District, Clewiston.

IMPORTANCE TO AGRICULTURE

Actually the plan will be of little use if it does not adequately concern itself with the welfare and development of agriculture. For Florida is essentially an agricultural state and will find an ever increasing need for growth in this field if the requirements of a rapidly increasing population are to be successfully met.

SUGAR CANE

We may have a change of opinion in Washington with respect to the production of sugar, and if that change of opinion comes

Figure 1.—Normal field of sugar cane capable of producing 40 tons of cane at maturity containing 3 to 4 tons of raw sugar per

about, it is ample demonstration of two things: first, that we *can* because we have successfully produced sugar; and second, that sugar cane plant will stand a lot of beating. The evidence is in the fields right now.

It is interesting to recall that the first agricultural development in the Everglades was based on sugar. There is no question whatsoever as to the possibility of expanding sugar operations as we do have the land and the experience as well as the necessary management. We lack two things: first, authorization by the Federal Government to increase sugar production; and second, the physical protection necessary against the very flood conditions which you can see all about in the lake area at the present time. Thus, no one would argue that the conditions shown in Figure 2 are satisfactory for sugar production and that the normal plant growth shown in Figure 1 is not much to be preferred for this purpose.

Figure 2—Sugar cane under flooded conditions in the Canal Point area which not only had a difficult time keeping off the red side of the ledger but even of surviving

FIBER CROPS

We are on the verge of a tremendous development of fiber plants in the Everglades, Figure 3. Unfortunately, ramie, one of the most important among them, is particularly susceptible to high water, Figure 4. Moreover, both Sansevieria and kenaf also are quite particular in their needs for water control whether growing on organic soils or the mineral soils adjacent, although not nearly as sensitive as ramie.

The comprehensive plan, which we have heard discussed, when put into operation should provide the necessary degree of protection and a real future for ramie and several other fiber

Figure 3—Normal growth of ramie on the organic soils of the Everglades Three cuttings from a stand of this type should yield at least 3/4 ton of dry, decorticated fiber per acre, per year

Figure 4—One of the early plantings of ramie at the Everglades Experiment Station (Autum 1929) showing wilting and loss of leaves during a period of excessive rainfall the following spring as a result of poor drainage Photo taken June 24, 1930

crops which are being investigated at the Everglades Experiment Station by State and Federal workers. There seems no question as to possibilities for these crops in this area extending almost beyond the average imagination. However, adequate control must be regarded as a prime prerequisite for the development of these crops.

LIVESTOCK AND PASTURE

Now we come to livestock. There are pastures throughout the Okeechobee and lower Glades area that are completely flooded at this moment. Conditions in the Lake Istokpoga area are much worse than last year and resemble a vast, almost limitless, lake. Only a couple of weeks ago the water was up to the running board of cars right here in the city of Clewiston. As a matter of fact, I am told that was the reason for delaying your meetings which were scheduled to be held here at about that time.

The two most important phases of livestock development which an adequate system of water conservation and control will assure in South Florida are: (1) Production of feeders on what we now call range cattle country to the north and west of Lake Okeechobee; and (2) The finishing of cattle in the upper Everglades. Today neither of the above are risks that any man cares to take even though many are doing it.

However, I am firmly convinced that given that degree of protection against floods, which will also enable the muck soil farmers to produce bumper crops of high quality corn for use in the cattle project, this Everglades Country will be turning out the highest grade of beef to be found anywhere. We've got to keep the grass and grow the grain. We will then make far better annual yields than any state in the south, whether it be corn or finished beef. The contrast of good and bad conditions, insofar as the livestock industry is concerned, is well shown in Figure 5.

Figure 5.—Part of the purebred Devon herd at the Everglades Experiment Station grazing Para grass "in depth." This is a most desirable contrast to the almost complete removal of the cattle population from the Glades proper following such storms as that of 1947. Such forced migrations are very costly in terms of time as well as animal losses. The only answer is *Water Control* and *Conservation*.

VEGETABLE CROPS

Vegetable farming is a gamble with unlimited room for expansion in this section of the State if needed. Aside from reducing and even eliminating some of the risks in this hazardous field, an improved water control system also is going to encourage some of the diversification that we have needed so badly in the agriculture of this section of the State.

OTHER BENEFITS

There are a lot of other benefits of which Mr. Scott has indicated a considerable number. Principal among them is, of course, the protection of the East Coast. Reference in this is not only to such catastrophic floods as have been experienced much too frequently in this area in the past, but also to the continuity of domestic water supplies through critical periods of drought which otherwise develop with about the same regularity as the floods unless the overall protection is developed against both sets of circumstances which Mr. Scott has discussed so ably. In other words, if we don't save water when we happen to have too much we certainly are not going to have it when there is too little, and when we need it badly, in consequence.

The Agricultural Interests and Chambers of Commerce have yet to fully appreciate the fact that the great conservation areas which are being set up in these sections (points to Mr. Scott's maps) with their extensive exposures of water surfaces will go far in restoring the mild winter temperatures that characterized the East Coast areas before the drainage of the Glades began.

Agricultural interests will benefit in this respect along with populous areas because sand land farming operations all up and down the East Coast, including the lower Glades which are very extensive, have suffered tremendously, not only from cold, but also from drought. In my own experience during the past 30 years in the Glades, I can vouch for the noticeably lower average winter temperatures which have been experienced. Incidentally, the State recently acquired an additional area of 50,000 acres for inclusion in this (points to "Hillsboro Lake" tract) conservation area with the proposal that the whole be turned over to the Wild Life Service of the U. S. Department of the Interior with the State retaining the water control rights on it.

A further benefit is to be found, of course, in the value of such conservation areas in the reestablishment of wild life in these sections such as in the so-called "Hillsboro Lake" section.

I can tell you for a fact that possibilities exist out in these areas for development along these lines which not even the wildest-eyed sportsman will believe until he has actually seen them. These natural benefits of the water storage areas contemplated in the plan together with the benefits they confer upon adjacent areas are really something to conjure with in contem-

plating the future possibilities for development in South Florida, agriculturally and in many other ways.

To my way of thinking the most outstanding benefit of this heroic plan to this great section of the State is, in effect, the removal of fear. By this I refer not only to the timidity of the individual coming into a country where such experiences as we have just gone through happen over and over again. Reference also is to the timidity of capital.

The development of this comprehensive plan which we have been discussing this morning will very definitely attract the kind of capital which took a chance when it came in here and built the sugar mill at Canal Point, or the one at Clewiston and the one over at Okeelanta; also the ramie development on the other side of the lake; and the many packing house enterprises in Belle Glade—they all took chances, most of them of a type that ordinary possessors of capital will not think of risking. We can now have real hope of putting development in this section of the State on a basis where much of that fear has been permanently removed. We must bring in the capital and the people that go along with it. To me such an accomplishment will be, by far, the most outstanding benefit of this plan to this area.

There are, of course, other points in the matter of fire hazards and other considerations that go along with Soil Conservation which are of extreme importance to the future development of this section of the State, which must be incorporated into this plan with great thoroughness and care.

In closing, I am impelled to point out that these people who you see working in the Everglades stay in this country because they love it. In fact, they love it so much that they have absorbed the floods, the fires and the winds through the years as matters of course. Certainly they are not the timid sort or they would not be here.

I can also tell you that they are not so calloused to the roughness of the treatment that they have experienced in the past that they will not appreciate the benefits of the plan we have been discussing and the relief from the perpetual fear that everyone feels while living under such conditions. They will not only appreciate these changes, but will take the fullest possible advantage of the benefits conferred by this plan, as it develops, in order to improve the use of the land and give it the better protection that it has needed so long through the physical facilities that, for the first time, will be available for this purpose.

DISCUSSION

Led By

Col. H. G. Matthews*

Col. Matthews: We have had a number of able, as well as some rather blind, discussions on the control of aqueous and sub-aqueous weeds. There also has been a considerable amount of discussion of water control, floods and drought. These tie together very easily, particularly in our flat country.

We must have adequate drainage canals that function efficiently. We are approaching the weed control problem as a means to an end in the water control effort. My job is to see that end arrived at for the State as a whole. We have a subcommittee of congress coming in, the chairman of which is from the Nevada mountains. Senator Malone has no conception of the flatness of this country; it is inconceivable to him that floods can lie on the land for so long. We must get these things across to him.

Water control benefits as they affect the whole State can be illustrated with a few simple facts. The State of Florida was the first portion of the United States discovered by the white man and still only 7 percent of the land of the State is developed after about 400 years. That is one thought. Another general fact is that a dead cow doesn't pay any taxes; a drowned out crop doesn't send kids to college, doesn't pay any bills. We are principally an agricultural State and any community is handicapped by floods. Under such conditions you are not going to have any major developments. People will be sparsely scattered over the area; property evaluations will be low; communication facilities will be developed to only a minimum degree, if they exist at all. Business and professional men in the area are going to be poor. Public health will be bad. In other words, we must get weeds out of the canals, dig more canals, set up proper water control works with proper reservoirs.

The problem is simple but it is going to take unity in this area and over the whole State to solve it. We are beginning to get that unity. We are going to need the help of the whole State to put this job over. Let us set up an arrangement or understanding whereby the rest of the State, in turn, can be helped. In other words, this can be treated as an economic thing which happens only once or we can look ahead a bit and see what we can do to get those benefits from planning to which we are entitled. I should now like to hear some discussion from the floor.

Harold A. Scott: I should like to mention a point here. Those familiar with the work that is going on with the comprehensive plan might wonder if the geological survey by Mr. Hoy, and the map which I submitted, offer a high probability that we may

*Chief, Division of Water Surveys and Research, Tallahassee, Florida.

run into difficulties. These porous rocks could very easily prove a boon to the comprehensive plan rather than the opposite. Why should we try to improve on nature. We do realize the problem that we are up against and we can provide the answer. The problem can be solved.

Lamar Johnson: The thing that is worrying me is the ability of the rocks to yield water. While they may be quite a boon to that end of the State, I am wondering if you find any differences in the ability of the rock to yield any water, as between the Tamiami limestone and the Miami Oolite, for instance?

Nevin D. Hoy: Geologically they are about the same on the average. This sample of Tamiami is very dense. It is generally uniform.

Horace A. Bestor: There is little public understanding of the resources of the State or any conception of what we are exploiting and wasting. The fertility of Florida soils is negligible for the most part. We must put something into our soils to get full value. The really great advantage is in the climate and in our generous water supply. Water is not alone the problem of flood control. The future of Florida depends on its water supply.

The condition of development that we are in now is relatively a pioneering situation. We seem never fully to have recovered from the storm of 1928. Development results to date all indicate that from the outset we have been largely dependent on water supply. We have already had considerable experience with a small group only in respect to municipal uses. During the development of the increased need of water, we are talking about industrial developments. However, we have no such water supply. The benefits of water are so great and the demand develops so fast and becomes so big that I doubt if there is anything in the way of public understanding.

Matthews: As estimated by the salt water encroachment on the present uses of water, etc., population of Florida would be limited by lack of water at a time when we arrive at about 3 times the present population unless we do something about it.

Bestor: I think that is a very conservative estimate. Nobody realizes what might happen until we reach a critical condition. That phase has not been appreciated. Even though we make mistakes we will learn by doing something consistently.

There is no question as to the hydrological advantages in having water control. We will, by storing and conserving our water, come close to restoring those natural conditions which we have so nearly destroyed. One thing we must remember and that is every drop of water that originates in South Florida that is useful comes from rainfall. There are no outside sources. We cannot do a lot of downhill draining. One only conserves this water by taking advantage of the things that are not going to bleed your land out but will hold your moisture. We can easily do this with the rainfall we have had even with beneficial flood

control heights. Damage is temporary. Put that water to a useful purpose.

R. V. Allison: In all this water storage talk there is a point we must remember. As soon as we begin to store water on a surface with a highly porous substratum we are going to lose that water through simple leakage. That is to say if Tamiami lime rock has the porosity of washed gravel, which the geologists claim it does, then it leaks and leaks badly and we might as well face this fact.

Indeed there are those who hold that the shallowness of the organic mantle to the South and over these areas of highly porous rocks is due to exactly that factor, leakiness. In other words, if your kraut barrel has even one hole in the bottom, you are not going to have a very good volume of kraut after the elapsed period of fermentation. All of this ties in to our overall question of soil losses in all parts of the Everglades wherever these organic soils are drained and tilled; and this brings up the further question as to where our agriculture is going when it has to leave the Glades!!!

While this insidious subsidence tendency can be delayed by the manner in which we handle these soils, we must nevertheless suffer a continuing loss at a rate that is roughly a straight line function of the depth to the water table.

However, the actual discussion of our agricultural outlook against the time the main body of the Everglades becomes non-arable should doubtless better be made the subject of another symposium. In the meantime, we should not forget the hard facts with which we are confronted and even keep in mind that abandoned agricultural areas of marsh soils which have been well fertilized during the period of cultivation are proving to be some of the finest wild life areas in the world. This is largely due, of course, to the great abundance of feed plants resulting from the substantial residue of plant food which has accumulated from the agricultural practices of the past. In the meantime, too, we should exercise every vigilance and spare no effort at improving both soil and water conservation practices in the whole area since the dissipation of the land itself through use can be greatly slowed down by the use of judicious management practices.

Johnson: I read an article a short time ago where agriculture in the West is pumping water from tremendous depths underground for agricultural purposes; and up in Washington Senator Malone only recently made a statement that he had just come from a conference on one of the projects in the West where they were considering pumping 1800 cubic feet per second from a level of 600 feet. We are not in that shape yet. Maybe we've wasted our water but we've pretty well replaced it during the last couple of years. Artesian wells don't rise 20 feet in the air but they can be pumped with a hand pump. It is truly time to do something about our water supply, but we are starting

pretty even with the exception of soil loss. We are much better off now as we still have water. Mr. Hoy, do you have any idea of the rate of salt encroachment along the East Coast?

Hoy: There is practically no salt encroachment in Dade County at the present time. During the past year and one-half canal flow proved sufficient to hold salt water back. Temporary dams also were placed. The experience was that the salt concentration passed from 1000 p.p.m. to 3000 over a period of six months and then moved back to 500. This is an overall value for observational purposes and has remained stationary except in the southern part of Dade County. The West Palm Beach area is still pretty well down. Southeast part of Florida remains about stationary at the present time. Not getting much better but it takes a lot of time.

Hoyt A. Nation: Dr. Allison mentioned it was desirable to have members of Fish and Wild Life Commission present at these meetings. What has the State Board of Health decided concerning spraying of 2, 4-D on these lakes and canals?

Allison: In further reference to my earlier remarks and, in fact, to the makeup of our present program, I do feel that the Fish and Wildlife people should be taking an increasingly active interest in the future development of the Everglades area. With regard to Mr. Nation's question, the Board of Health will now approve the use of 2, 4-D, provided it does not contain free phenol, at least in the amount that we can do the job with. Since there is no free phenol in 2, 4-D, we should have a considerable degree of freedom in its use insofar as toxicity to fish, domestic animals, etc., is concerned.

Johnson: The freedom of this material from toxic principles surely needs some good publicity.

J. E. Beardsley: Called attention to current report in paper of a Government committee of 21 that had been appointed to review the COMPREHENSIVE PLAN and work with local and State boards as well as the Corps of Engineers. There are to be 8 members from the State Legislature and 13 citizens at large. We are fortunate that Senator John Beacham, of West Palm Beach, and Mr. B. Elliott, of Pahokee, are named to that committee. We in the Glades are exceedingly fortunate in that a staff member of the principal metropolitan newspaper of South Florida, a very worthy friend who has done us tremendous service, and who I am happy to say this morning has been nominated to that committee is here, present with us—Jeanne Bellamy.

Shortly following the introduction of Miss Bellamy, Col. Matthews called attention to the lateness of the hour, 12:30 P.M., Saturday morning, and closed the discussion forthwith. A motion for adjournment was made immediately thereafter and, upon favorable voice vote the meeting was formally closed by Chairman Bestor.

BANQUET AND BUSINESS MEETING

The Ninth Annual Banquet was held at the Clewiston Inn on the evening of October 12th, 1948. The Guest Speaker for the occasion was Mr. Lewis S. Evans, Plant Industry Station, U. S. Department of Agriculture, Beltsville, Md. Mr. Evans' address "The National Weed Control Program" is printed in full in this volume on pages 9-14, inclusive.

BUSINESS MEETING

The reading of the minutes of the past meeting was dispensed with and the report of the Secretary and of the Editor were each of an oral nature. The report of the Treasurer, to be made at the close of the calendar year, was ordered audited at the proper time by the following committee: D. W. Smith, Chairman; T. C. Edwin and J. C. Hoffman.

REPORT OF THE NOMINATING COMMITTEE

In view of the recent resignation of the Vice President of the Society, Dr. Lewis H. Rogers who had accepted a position with the Oak Ridge Project prior to the meeting, it became necessary to elect a president as well as a Vice President for the coming year and the Nominating Committee was so instructed by the Chair at the time of their appointment early in the meeting.

In making their report, the Committee submitted their choice of Dr. W. T. Forsee, Soil Chemist, at the Everglades Experiment Station Belle Glade, for President and Dr. R. A. Carrigan, Biochemist and Spectroanalyst in the Soils Department of the College of Agriculture, Gainesville, for Vice President. The Chair then called for nominations from the floor. None were offered. A motion was then made and seconded that the Secretary be instructed to cast a unanimous ballot for the slate that had been offered by the Nominating Committee. This action was approved by oral vote with no dissent. The new officials were duly inducted into their respective offices immediately prior to the close of the meeting.

MEETING OF THE EXECUTIVE COMMITTEE

A very brief meeting of the Executive Committee was held immediately following the close of the business meeting especially to appoint a Secretary-Treasurer and to discuss the dedication of the forthcoming volume of the Proceedings, No. IX, covering the meetings just concluded.

In filling the post of Secretary-Treasurer, R. V. Allison, Everglades Experiment Station, Belle Glade, was again appointed. In respect to the dedication of the Proceedings it was unanimously decided to request of Colonel Willis E. Teale the

privilege of dedicating it to him in recognition of the great and good work he, as District Engineer, and his associates in the Jacksonville District Office, Corps of Engineers, have done during the past few years in the development of a UNIFIED PLAN OF WATER CONTROL AND CONSERVATION for Central and South Florida in close cooperation with State, Federal and local agencies. The Secretary was instructed to contact Colonel Teale and learn his pleasure in this matter.

RESOLUTION OF SYMPATHY

Soil Science Society of Florida

Whereas, death has taken from our rolls during the year the following esteemed members of the Society whose sincere and constructive interest in all aspects of the work will make their absence keenly felt for a long time to come,

Now Therefore, Be It Resolved, that this expression of sorrow over this great loss and of sympathy to the immediate families of the deceased be spread upon the records of this Society and a copy of same be sent to the closest member of the family of each.

Mr. J. C. Adderly
Molino, Florida

Mr. G. J. Barstow
South Bay, Florida

Mr. Rex Beach
Sebring, Florida

Dr. Charles E. Bell
Gainesville, Florida

Dr. William J. Buck
Belle Glade, Florida

Mr. Joshua C. Chase
Winter Park, Florida

Dr. A. P. Dachnowski-Stokes
Riverside, California

Dr. R. O. E. Davis, U.S.D.A.
Washington, D. C.

Mr. William A. Desnoyers
Belle Glade, Florida

Dr. John C. Gifford
Coconut Grove, Florida

Mr. W. B. Granger
Belle Glade, Florida

Dr. G. B. Sartoris
Washington, D. C.

Mr. Frank Stirling
Ft. Landerdale, Florida

Mr. W. E. Stokes
Gainesville, Florida

Mr. L. L. Stuckey
Pahokee, Florida

Mr. Arthur E. Taylor (4-3-47)
U.S.D.A., Washington, D.C.

Mr. B. McE. Whitlock
Palm Beach, Florida

By the Resolutions Committee,
Luther Jones, Chairman.

William A. Desnoyers

On the afternoon of October 13th, 1948, in the course of a demonstration of airborne spray equipment in the Clewiston-Moore Haven area, Mr. Desnoyers was so unfortunate as to take a position directly in the line of flight of the spray plane, apparently with the idea of photographing the equipment in action both as it approached his position and as it left it.

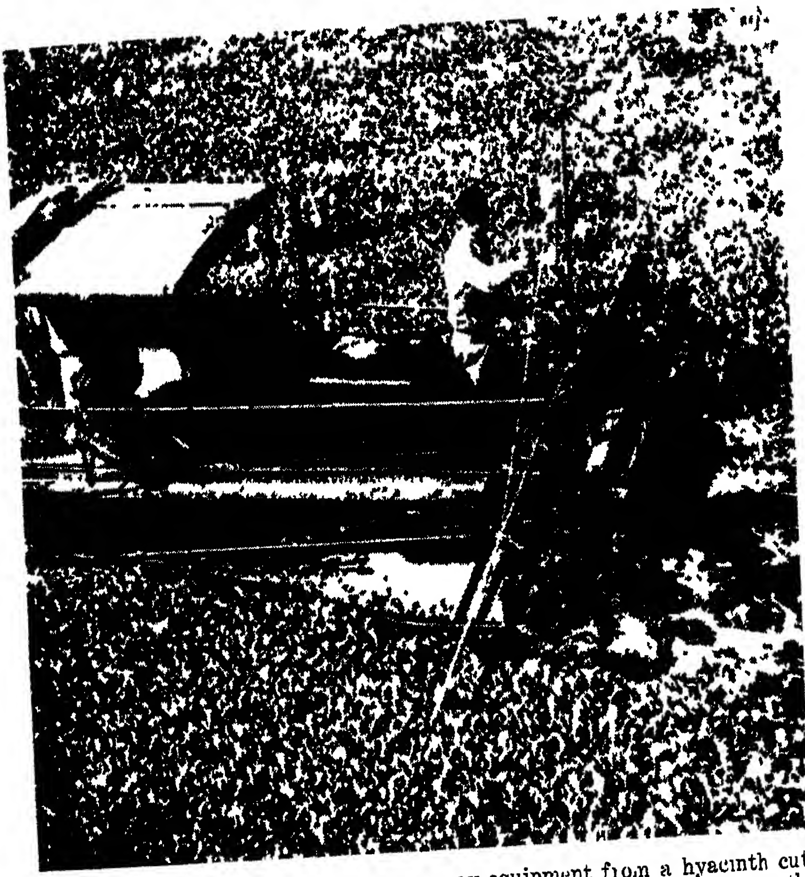
The suddenness of his decision to do this must be obvious from the fact that he must have taken the position after the plane (an N3N biplane) had fully completed its turn and settled down towards the run that had been decided upon for the demonstration; for the pilot could not possibly see an object directly in his immediate path at such a time, especially after he had viewed the run as fully clear at the turn.

While a critical examination of the plane following the accident failed completely to show the place or nature of the impact, death was instant.

In commenting on this tragic happening, Mr. Leo. L. Burnet, Chief, Engineering Division, Jacksonville District, Corps of Engineers, had the following to say:

> "This office was indeed sorry to hear of the fatal accident to Mr. William Desnoyers. Inasmuch as he had worked alongside of several of the people from our office in the experimental work on hyacinths at Mulberry, this office in a measure shares with you in this loss.
>
> "Inclosed is a photograph of Mr. Desnoyers operating spray equipment from the stern of a hyacinth- destroyer boat at Mulberry, Fla., in April of this year. In view of his interest and contribution to the work on water hyacinth control investigatigations, it is thought his family might like this picture."

It is in view of Mr. Burnet's thoughtful suggestion and contribution of the photograph that it is published in these Proceedings, the original copy having been sent to Mr. Desnoyers' family along with this attendant record.



Mr. William A. Desnoyers operating spray equipment from a hyacinth cutter in a cooperative study with the Corps of Engineers, U. S. Army, in the Mulberry (Fla.) area.

HORACE A. BESTOR

OFFICERS OF THE SOCIETY

1946-47

HORACE A. BESTOR .... President
(Clewiston)

LEWIS H. ROGERS .... Vice President
(Gainesville)

HERMAN GUNTER .... Mbr. Exec. Committee
(Tallahassee)

R. V. ALLISON .... Secretary-Treasurer
(Belle Glade)

APPENDIX

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THE HYACINTH ERADICATION PROGRAM OF EVERGLADES DRAINAGE DISTRICT, FLORIDA, 1946-1948

General Area

The main body of organic soils of the Everglades extends from Lake Okeechobee to the southernmost tip of Florida. This area is approximately 40 miles wide and 100 miles long and is bounded on the east and west by mineral soils of higher elevation. This flat expanse of organic soils was originally the natural floodway for the overflow of Lake Okeechobee and the runoff of the surrounding higher lands.

In the process of reclamation, canals were constructed from Lake Okeechobee in an easterly and southeasterly direction to a connection with short coastal rivers, or other natural outlets, discharging into the Atlantic Ocean. These main arterial canals were four in number, varying in length from 40 to 80 miles and in width from 60 to 110 feet. Several smaller east-west canals complete the arterial system of canals, now independent of the control system for Lake Okeechobee.

By 1946 the existing arterial canal system had become choked with hyacinths and reduced approximately 50% in efficiency. Because of the inadequacy of this system to serve agricultural development, and because monies for structural improvement of the system were not in prospect, a hyacinth clearance program seemed the only way to increase the efficiency of the system within the means available.

The Arterial System—Then and Now

Two years ago, mid-year 1946, the total arterial canal system was largely overgrown with water hyacinths. For years these plants had flourished almost undisturbed even by serious frost-kill. Maintenance had almost ceased after the bankruptcy of Everglades Drainage District in 1930. The hardy growth of plants, generally 24″ to 36″ in height, had created a matted root blanket from bank to bank that continued for miles along most of the canals. Few places in the world, if any, can excel the Everglades in ideal growing conditions for the water hyacinth.

The only exceptions to this general rule were the lower reaches of the Miami Canal, where infestation had never been serious for some reason, and in the West Palm Beach Canal. The latter canal was only about 70% covered because of efforts in prior years, by the District and other agencies, to keep the channel open by "drifting."

The history of the water hyacinth in the arterial canal system of the Everglades is a comparatively short one. Contami-

nation began as soon as the canals were connected with Lake Okeechobee, generally about 1918. During the next ten years the use of the channels for navigation supplied some degree of control. However, by the middle 1920's it was necessary to equip a clamshell dredge with a special bucket for occasional use in clearing hyacinth jams from the channels. With the construction of highways into the Everglades, the use of the canals for navigation rapidly decreased. The financial difficulties of the District after 1930 removed the last block to the hyacinth's expansion and the canals were soon covered.

By 1935 means were being sought to clear the canals to provide better drainage. In 1934 and 1935, the Port of Palm Beach District spent approximately $10,000. on hyacinths in the West Palm Beach Canal in an effort to maintain navigation for the transport of materials used in the construction of control structures in the U. S. Government Levee around Lake Okeechobee. In 1936 the Works Progress Administration and the State Road Department cooperated in an expenditure of several thousands of dollars to remove the hyacinths from this same canal. This project was interrupted by the U. S. Engineers in objecting to the discharge of hyacinths into Lake Worth and the Inland Waterway. The U. S. Engineers, in 1939, made available the sum of $10,000. to clear the West Palm Beach Canal of hyacinths provided Everglades Drainage District would agree to maintain the channel clear thereafter. The District agreed and the project was undertaken. The U. S. Engineers, in 1940, also cleared 8 miles of the upper Hillsboro Canal, 18½ miles of the upper North New River Canal and 12 miles of the upper Miami Canal. After this clean-out, the District and the Engineers agreed to maintain specified parts of each cleared section in a clean condition thereafter. Both agencies failed in this agreement.

After the District's defaulted indebtedness was settled, and limited funds were again available for maintenance work, the District tried to improve the hyacinth situation. In 1943 and 1944 approximately $6,000. were expended annually on hyacinth control. In 1945 approximately $9,000. were expended. The bulk of this work was done on the West Palm Beach, North New River and Bolles Canals. The method of control generally used was drifting the hyacinths downstream into the ocean, although a limited amount of removal by dragline equipment was undertaken. An experimental stretch of one-half mile of hyacinths was removed from the Hillsboro in 1944, at a cost of $1,647.00. Much of the expenditure during these three years was on the West Palm Beach Canal in a losing battle to maintain an open channel in the canal.

The picture today is entirely changed. The arterial canals are nearer being free of hyacinths than at any time since the middle 1920's. The channels of the three major canals are entirely free of hyacinth jams, even at the many obstructing bridges. The only jams that cannot be eliminated are those near

the upper ends of the canals where booms have been constructed to prevent infiltration of hyacinth from Lake Okeechobee. Only the occasional hyacinth plant or small group of plants remain to receive the attention of the patrol boats in the routine control program in these canals.

The District's Hyacinth Program

Chronology—

Spring, 1945—Everglades Experiment Station made first tests with 2, 4-D (2, 4-dichlorophenoxyacetic acid) on hyacinths in Hillsboro canal and found it entirely effective.
Fall, 1945—Everglades Experiment Station expanded experiments with 2, 4-D.
March 7, 1946—Appropriation made to Everglades Experiment Station to expand experiments with herbicides.
April, 1946—Experiments expanded to include spraying by aeroplane.
June 6, 1946—Everglades Drainage District authorized project and appropriated funds for program of clearing 178 miles of the main canal system.
June 21, 1946—Crop liability insurance coverage obtained.
June 22, 1946—Contract let for aeroplane spraying of 114 miles of arterial canal.
July 4, 1946—Began aeroplane spraying using diesel oil mix.
July 8, 1946—Began spraying by boat.
Sept. 7, 1946—Second phase of aeroplane spot treatment of jams begun.
Dec. 1, 1946—Seasonal cessation of spray program.
Feb. 1947—Test sprayings for observation of results in early spring.
Mar. 1, 1947—Floods delayed start of spring program.
Mar. 21, 1947—Began spring program.
May 5, 1947—Amphibian "shoes" put to work.
June 1947—In flood emergency, curtailed spray program.
Oct. 1947—Flood emergency halted spray program.
Nov. 7 to Dec. 12, 1947—Limited spraying by boat.
Jan. 17, 1948—Began spring boat spraying program.
March 1948—Began moving remaining jams from major canals.
July 31, 1948—162 of original 178 miles of canal entirely on patrol basis.

Procedure

In the fall of 1945, the Everglades Experiment Station at Belle Glade, Florida, obtained small quantities of 2, 4-D with which to begin experimental work. Most of these materials were in dust form. Some of these limited amounts of materials were used experimentally in distribution by aeroplane on hyacinths in a short section of canal. Results of these early experiments

were encouraging but showed the need of developing the correct method of application and control.

During the next few months many new formulations of 2, 4-D became available for experimental work. Realizing the possibilities of this herbicide as a means of fighting the hyacinth problem, the Board of Commissioners, on March 7, 1946, appropriated $500.00 to be used largely to purchase materials with which to conduct hyacinth experiments. Experimental work with aeroplane spraying was begun extensively in April, 1946. Various formulations of 2, 4-D at different rates were applied.

As a result of these experiments the following basic conclusions were reached that determined the type and scope of the hyacinth eradication program later authorized by the District:

1. That unit for unit of the killing component, sprays were more effective than dust and generally easier to control in application.

2. That a rate of 200 gallons per acre of a spray containing 1000 p.p.m. of 2, 4-D was generally suitable in hyacinth eradication work.

3. That certain types of agricultural plants were very sensitive to 2, 4-D.

4. That 2, 4-D was non-toxic to fish and cattle in the concentrations used.

5. That spraying by aeroplane was feasible and economical of use in hyacinth eradication work on the District's canals.

6. That the use of spray boats to clean up behind the aeroplane and to later patrol the canals was evident.

On June 6, 1946, the Board of Commissioners of Everglades Drainage District authorized a hyacinth program embracing 178 miles of the arterial canal system. Of this total, it was proposed that 114 miles be sprayed by aeroplane and 64 miles by boat. Most of the proposed boat work was on the West Palm Beach canal where efforts at control had been made in prior years and the cover was not as extensive or densely matted. The cost of eradication to reach the patrol stage was estimated at $45.40 per mile or a total of approximately $8,000.00. The program was from time to time extended to cover additional mileage and the estimated cost was much less than actually expended. This estimate is cited in this paper to show what can be expected in the way of cost under optimum conditions that never occurred in the District's program.

Insurance coverage on crop damage as a result of the spray program was obtained June 21, 1946. No claim was ever made under this policy and the premium was reduced 30% after the first year. Obtaining crop liability insurance of this type was difficult as there was no precedent or established rate. This necessarily delayed letting the contract for the spray work.

The contract was entered into the following day, June 22, 1946, at a base rate of $0.75 per acre of hyacinths sprayed. Specifications called for spraying the center area of each canal

"to within a few feet of the channel edge." It was proposed to make the first application at the rate of 750 p.p.m. as compared with the standard rate of 1000 p.p.m. in 200 gallons of water per acre. In the type of aeroplane equipment used, this was the equivalent of 3 pints of 40% 2, 4-D product in 2 gallons of water per acre. The proposed second treatment, to be applied approximately two weeks later, was to be at a rate of from 75% to 100% of the first application, as determined by then existing conditions. As it developed, this rate of application was never followed.

The type of aeroplane equipment used consisted of N3N biplanes powered with a 250 horsepower motor. A spray boom was rigged under the surface of the lower wing and fitted with spray nozzles spaced 18 inches apart on the boom. An operating pressure of 50 pounds per square inch was developed by a small marine gear pump driven by an auxiliary propeller. A 50 gallon tank was mounted in one cockpit of the aeroplane as a supply tank.

The original program of spraying by aeroplane using water as the carrier had several serious weaknesses, the most important of which was the loss of effect of the killing component if it rained on the sprayed area within a few hours after the spray work was completed. Another was the failure to get coverage to the edge of the canal channel. Consideration had been given to oil as a carrier. On July 4, 1946, an experimental stretch of canal was sprayed using No. 2 diesel oil as the carrier. The results were very satisfactory, giving much better coverage and a better kill.

Thereafter diesel oil was used almost entirely. The spray boom was changed to a section of electrical conduit with No. 70 sized holes drilled at 1½ inch intervals. This part of the equipment has again been changed with the availability of better designed nozzles and cut-offs that prevent "drip." After the decision to use oil in the spray, it was found that only one of the formulations of 2, 4-D was miscible in oil. Fortunately we had used this formulation in the experimental work. Emulsifying agents were tried with no success. Unfortunately, the formulation that was miscible in oil was one of the highest priced on the market, but it was considered that the increase in results was worth the additional cost. The price has since been substantially reduced.

These developments changed the original program somewhat. It was found that a smaller dosage obtained satisfactory results. It developed that a complete second application was not the economical method to use. As it resulted, the canals designated for aeroplane spraying were sprayed one time over by August 31, 1946, and the dying hyacinths allowed to sink and clear up as much possible. The aeroplane program was expanded to include nine miles of the upper Miami Canal. In this first phase, 1259 acres, the rate of application averaged 0.8 quart of 40%

butyl ester carried in approximately 3 quarts of No. 2 Diesel oil per acre.

This first application resulted in approximately an 80% kill and the costs were as follows:

Herbicide cost per acre	\$2.109
No. 2 Diesel oil cost per acre	0.076
Application cost per acre	0.775
Per Acre Total	\$2.958

On July 8, 1946, the boat-spray program was commenced in the West Palm Beach Canal. A flat bottomed "frog-boat" hull powered by a 10 horsepower outboard motor was used. The spray equipment consisted of a conventional 20 g.p.m. orchard spray pump driven by an air-cooled motor, a "boom-type" spray wand and a 50 gallon supply tank. This was a two-man operation. The mixture used was at the rate of 1000 p.p.m., being one pint of 40% formulation of 2, 4-D in 50 gallons of water.

Where there was any open channel in the canal, the boat worked well. At first, it was attempted to force the boat through the hyacinth jams by cutting a path with machetes. This was slow and costly and the procedure evolved into portaging the boat around the jams, spraying where there was any open channel. Later the jams were sprayed by aeroplane.

In early September 1946, the second phase of the aeroplane spray program was begun. Obviously, the existing situation did not permit employment of an aeroplane on an acreage basis. Thereafter, all such spray work was done on an hourly contract agreement.

The condition met here was the result of dead hyacinths sinking and loosening the original matted surface to an extent that permitted both remaining dead hyacinths and live hyacinths to drift with wind and current and form considerable jams at the numerous short-span bridges over the canals. These jams delayed the time that the spray boats could navigate most of the canals in a clean-up program. This added immeasurably to the ultimate cost of the hyacinth eradication program. In contrast to the general condition, the West Palm Beach Canal, where there are few short-span bridges, was substantially on a patrol basis a full year before the other arterial canals.

During this phase of the program, the aeroplane was utilized in spraying the jams as they formed. Regrowth of the hyacinths was a factor and the inability to combat this regrowth successfully was discouraging. The problem accentuated the need of some method of control during the period between the spraying of a covered channel by aeroplane and the opening of a channel that a boat could navigate. A spraying arrangement on the wingtip of the aeroplane was tried without any large degree of success. This problem of control in the interim

between the aeroplane and the boat resulted in the construction of an amphibian machine for this job the following spring.

Cool weather by December 1, 1946, halted the hyacinth spray program. While the plants were not winter-killed they were dormant to the extent that their reaction to the herbicide was unsatisfactory.

In February, as the weather became warmer generally, test experiments were made at several points by the aeroplane to determine at what stage the hyacinths would react sufficiently to the herbicide to justify the cost involved. It was soon learned that we must be content in the spring to wait until the hyacinth is actively growing before it reacts favorably.

On March 1, 1947, a six-inch rainfall blanketed the upper 'Glades, creating floods that delayed the spring program until March 21st. Beginning on that date, the aeroplane began the spraying of jams in the channel and the boat began the routine spraying of the edges of the West Palm Beach Canal. A second boat was put in operation equipped with a 12 g.p.m. orchard spray pump. Some infiltration of hyacinths from connecting ditches and borrow pits occurred during this early flood, but to no serious extent.

The amphibian spray machine was ready for its part of the program on May 5, 1947, after being constructed in the shops of the Everglades Experiment Station at Belle Glade, with the assistance of the Station's personnel. This contrivance was assembled from a three-quarter ton four wheel drive chassis and wheels constructed from 6'-6" diameter pressed steel telephone cable reels. The face of the reels was banded with marine plywood to provide flotation for the vehicle within the wheels. Flotation being in the wheels, the rig was promptly dubbed "Jesus Shoes." A six horsepower air-cooled motor powers the vehicle, driving through a 15:1 reduction gear ahead of the conventional transmission. The spray equipment comprises a 12 g.p.m. orchard spray pump powered by an air-cooled motor, a 50 gallon supply tank and broom type spray wand. This also is a two-man operation piece of equipment.

In operation, this machine demonstrates its place in the program. It travels over jammed hyacinths easily and is reasonably dependable. It is adaptable to any problem where aeroplanes cannot spray and the boat cannot navigate.

By the last of June the District was in flood difficulties. The spray program was curtailed; in fact, it was entirely stopped at times. Canals were generally out of their banks, making effective spraying impractical. Most expenditures during July were for removing jams of dead hyacinths from each bridge location in the interest of better flood discharge.

The peak of the flood was reached near the middle of October, 1947, and all spray work was stopped. The Everglades were almost entirely under water to a depth of two or three feet and a general overland flow to the south and southeast resulted. Hya-

cinths from many farm and levee ditches floated with the flood crest and drifted with the currents. As most of the arterial canals have a roadway on their south or southwest banks, the drifting hyacinths collected in the canal channels. Efforts were directed toward keeping serious hyacinth jams from forming at the numerous bridges and controls in the canals in order that the channels could operate as efficiently as possible. The cost of this work has been charged against the hyacinth program, but it is possbile that the correct charge would have been to flood emergency.

It is impossible to evaluate the benefit of the hyacinth program to the Everglades during the 1947 flood. It is a fact that the arterial channels were even then considerably more efficient at comparable stages within the channel than they were when they were blanketed with an extensive hyacinth mat. How the hyacinth blanket would have influenced the channel action with the banks submerged from two to three feet generally is a debatable point. It is certain that a decrease of overland flow southward would have resulted if the hyacinths had been available in sufficient quantities to block the openings in that direction. Jams at bridges and controls would undoubtedly have been a serious threat to canal blockage and a greater danger of probable damage to the structures themselves. Without question, had the 1947 flood occurred two years earlier, the duration of the flood would have been longer and stages generally higher.

Spraying by boat was again undertaken on November 7th in an attempt to keep the natural growth and spread of the hyacinths in the canal under control. As the canal banks were still flooded this work was not too effective but was continued until December 12th when cooler weather produced a mild degree of dormancy in the hyacinth plants.

The spring spraying program for 1948 was begun on January 17th. The winter had been mild and the warm weather in January caused the hyacinths to begin to grow. The canals were within their banks and the hyacinths once more confined to the channel. From a standpoint of progress, the program was only slightly advanced from the stage it occupied in the spring of 1947. The channels were generally bordered along their edges by a fringe of hyacinths and extensive jams were numerous, especially at bridge crossings of the channel. However, some of these jams were loosely packed and could be traversed by boat without too great a difficulty.

Profiting by the experience obtained in 1947, efforts were concentrated on one canal at a time to clear that particular channel to navigation by spray boat. Three boats were normally used but two boats and the "Shoes" sometimes made up the spray team. One boat patrolled the channels or parts of channels as they were cleaned and in need of patrol spraying. At the beginning of the year, the West Palm Beach Canal was the only channel navigable by spray boat throughout its length.

As each canal was sprayed and the dying hyacinths began drifting downstream to collect at bridges and controls, a crew of men was used on a full time basis to keep the jams broken up and drifting toward the ocean. This operation was costly but was justified by the results, for as soon as a channel was cleared of jams to permit free passage of the spray boats, the main fight was over.

Cost of the Program To Date

The following annual and total cost reflects all cost except general office supervision. Most overhead costs, as crop liability insurance, are included. Many labor items are included that possibly are chargeable to flood emergency work, but were too involved to separate.

ANALYSIS OF COST OF HYACINTH PROGRAM BY EVERGLADES DRAINAGE DISTRICT

A—Materials and Equipment

Year	2, 4-D Spray Materials	No. 2 Diesel Oil	Equipment and Repairs	Aeroplane Contract	Experi-mental Work	Annual Total
1946	$6,217.98	$245.15	$2,553.76	$2,495.55	$428.15	$11,940.59
1947	9,018.76	347.34	2,526.89	3,273.15		15,166.14
1948 (7 mos.)	4,537.45	21.45	895.40	241.66		5,695.96
Totals	$19,774.19	$613.94	$5,976.05	$6,010.36	$428.15	$32,802.69

B—Labor

Year	Boat and Shoes Spraying	Removing and Drifting Jams	Field Supervision	Miscel. Labor on Equipment	Annual Total
1946 (6 mos.)	$ 1,516.00	$ 467.00	$ 120.00		$ 2,103.00
1947	3,690.83	1,852.68	840.00	$165.00	6,549.18
1948 (7 mos.)	4,832.44	2,874.57	1,410.00	475.00	9,592.01
Totals	$10,039.27	$5,194.25	$2,370.67	$640.00	$18,244.19

C—Summary

Year	Materials and Equipment	Labor	Annual Total
1946	$11,940.59	$ 2,103.00	$14,043.59
1947	15,166.14	6,549.18	21,715.32
1948	5,695.96	9,592.01	15,287.97
Totals	$32,802.69	$18,244.19	$51,046.88

For the amount expended the following channels have been cleared and are on a patrol program basis:

Canal	Width in Feet	Length in Miles	Remarks
West Palm Beach	65-110	40	Original Program
Hillsboro	60-100	50	Original Program
North New River	60-100	59	Original Program
Cross Canal	35-60	13	Original Program
South New River	60-90	7	Expanded Program
Dania Cutoff	60-90	4	Expanded Program
Big Mound	35-60	4	Expanded Program
Total		177 Miles	

In addition, 16 miles of the Bolles Canal and 8 miles of the upper Miami Canal are partially cleared. Work now being done to place these canals on a patrol basis should be completed this year.

THE DISTRICT'S FUTURE HYACINTH PROGRAM

It is the objective of the Board of Commissioners of Everglades Drainage District to extend the hyacinth eradication program as funds become available until the entire canal system of the District has been cleared. Constant patrol work is necessary if the channels are to remain cleared and plans are in process for the accomplishment of that part of the program as economically as possible. The cost of the patrol work is estimated to cost less annually than the $9,000. spent on hyacinth work in 1945—the last full year before spraying began. As more ditches and canals connecting with the arterial system are cleaned, outside infestation to the District's canal should lessen and the cost of patrol operation decrease.

A new type of spray boat is now being constructed for patrol work. The hull is of light framework covered with marine plywood. It will be powered with a 5 horsepower outboard motor. The spray equipment will be a low pressure, low volume type using a small gear pump and small air-cooled motor. The type of boom or wand must still be determined by trial and error, but will probably be a wand about nine feet in length with selective nozzles. This equipment will be one-man operated and it is proposed to work the boats in pairs to reduce cross-drift of hyacinths by wind during the spraying period.

WORK BY OTHER AGENCIES AND INDIVIDUALS

Throughout the Everglades numerous sub-districts and individuals have initiated spray projects on a smaller scale in the secondary canal system. Each undertaking encountered its own problems, but results have been generally satisfactory. All types of spraying equipment are being used, including the aeroplane and the boat. Much of the work in the smaller channels has been accomplished by land equipment spraying from the banks. Good work has been accomplished, but the need of periodic maintenance spraying to keep the channels clean has not been recognized in many instances.

Dade County has aided the Everglades Drainage District by including in their spray project 40 miles of the District's secondary canal system. In addition, 16 miles of coastal canals and ditches have been sprayed. In its work, this county utilized an army "duck" to some extent for a part of the work, but are now using a boat as the vehicle.

CONCLUSION

The District's program is visible evidence of the feasibility

of clearing channels and controlling water hyacinths by spraying with 2, 4-D.

The cost to the District has been greater than originally estimated for three reasons:

1. The experimental nature of the project.
2. Inability to forsee the problems that would be caused by jams at bridges and other channel obstructions, preventing early clean-up of the edges by boat spraying.
3. Delay and infestation caused by the 1947 flood.

It is evident that diligent patrol of a channel is necessary to maintain the channel in a clean condition. This patrol should be at intervals that prevents the maturity of a new seed crop. It is also evident that regrowth from rhizomes is almost absent in the young plant after it is sprayed, which is contrary to the reaction in old, vigorous plants.

It is evident that legislation will be required to protect channels that are being patrolled from deliberate contamination from connecting streams and lakes.

Research developing a chemical formulation that would speed the rotting and disintegration of the dead hyacinths would hasten the opportunity for boat clean-up and be helpful in any program. In the Everglades, a spray formulation that would kill and control Para grass would permit further clean-up of channels and farm ditches to the benefit of the whole program. This is also true of several aquatics that are a part of South Florida's problem.

Expansion of any hyacinth eradication program to embrace an entire watershed area would be the economical way to combat hyacinths from the long-range viewpoint. The experience gained by the District's project indicates that regrowth lessens with systematic patrol and it is believed that complete eradication is not an impossibility within a complete waterway system.

BOARD OF COMMISSIONERS
EVERGLADES DRAINAGE DISTRICT

Release authorized by
Board of Commissioners
August 5, 1948
Prepared by:
Lamar Johnson,
Engineer.

THE SOIL SCIENCE SOCIETY OF FLORIDA

PROCEEDINGS
VOLUME X
1950

Tenth Annual Meeting of the Society
Winter Haven
June 21, 22 and 23, 1950

OFFICERS OF THE SOCIETY

1951

RICHARD A. CARRIGAN	President
I. W. WANDER	Vice President
W. T. FORSEE, JR.	Member Executive Committee
R. V. ALLISON	Secretary-Treasurer

Retiring Officers listed on page 269

ACKNOWLEDGMENTS

The Executive Committee, in behalf of the entire membership of the Society, wishes to express its sincere thanks to Commissioner Mayo and his Associates for the generous use of the Florida Citrus Building at Winter Haven and to Mr. Frank L. Holland, Manager, Florida Agricultural Institute, for his good help in so many ways in making local arrangements.

They also desire to express the good fortune they feel in having such distinguished workers from out of State present and take most valuable parts on the program as: Dr. I. J. Cunningham (New Zealand), Prof. A. L. Lang (Illinois); Drs. W. L. Nelson and Wreal L. Lott (North Carolina); Dr. Vincent Sauchelli (Maryland); Dr. Robert E. Lucas (Indiana); Dr. E. R. Purvis (New Jersey); Dr. James A. Naftel, (Alabama) and Major W. O. Robinson, Washington, D. C. (U.S.D.A.). They do have our very best thanks.

We feel no less gratitude, assuredly, to those workers in other countries who, though they could not be present at the meeting, went to great pains in preparing excellent manuscripts on the subject assigned in the effort at a broad review of trace element work in its relation to plant and animal health and growth on a world wide scale. These include Dr. Katherine Warington, Rothamsted Experimental Station (England); Dr. E. G. Mulder (Holland); Drs. H. G. Green and Ruth Alcroft, Veterinary Laboratory, Weymouth (England) and Mr. D. S. Riceman (Australia).

Finally, we are most particularly indebted to Dr. Edward M. Redding. Director of Research at the Charles F. Kettering Foundation, Dayton, Ohio for his splendid after dinner address. This gave us a most extraordinary insight into the vast role that chlorophyll plays in the development and maintenance of life on the earth in which it serves as an amazing link of great power and vast mystery between the Sun and the Soil.

SUSTAINING MEMBERS

(1950)

Allee, Dr. Ralph H., Turrialba, Costa Rica

Allison, Dr. Ira, Springfield, Mo.

American Cyanamid Company, Brewster, Fla. and New York, N. Y.

American Potash Institute, Inc. Atlanta, Ga.

Andrews, Charles O., Jr., Orlando, Fla.

Ariens, Mando S., Brillion, Wis.

Arthur, A. F., Goulds, Fla.

Babcock, Vose, Coral Gables, Fla.

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Brown, Harry C., Clermont, Fla.

Cabassa, Jacob L., Miami, Fla.

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Dodson, C. H., Miami, Fla.

Dolomite Products, Inc., Ocala, Fla.

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Du Pont de Nemours & Co., Inc., E. I., Wilmington, Del.

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Everglades Drainage District, West Palm Beach, Fla.

Falla, Alejandro Suero, Havana, Cuba

Fellsmere Sugar Producers Association, Fellsmere, Fla.

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Gier, Raymond F., Ft. Lauderdale, Fla.

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Jones, Luther, Belle Glade, Fla.

Klee, W. H., Jacksonville, Fla.

Knight, T. W., Belle Glade, Fla.

Lindo, Hon. Roy D., 32-34 Port Royal St., Jamaica, W. I.

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Magoffin, J. E., Kingsport, Tenn.

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Meyer, Byron F., Miami, Fla.

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Morrell, Albert, Orlando, Fla.

Neiman, Harry, New York, N. Y.

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Norris Cattle Company, Ocala, Fla.

O'Kelley, E. B., Jacksonville, Fla.

Palm Beach County Resources Development Board, West Palm Beach, Fla.

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Peters, Frederick C. (Farsouth Growers Coop. Assoc.), Miami Beach, Fla.

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Preston, Hayden, Tampa, Fla.

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Rolston, W. A., Houma, La.

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Scott, Ed, Everglades, Fla.

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U. S. Phosphoric Products, Tampa, Fla.

U. S. Sugar Corporation, Clewiston, Fla.

Waring, W. L., Tampa, Fla.

Washington Technical Services, Washington, D. C.

Weiss, M. M., Miami, Fla.

Weston, J. W., Ft. Lauderdale, Fla.

White Belt Dairy, Miami, Fla.

Wilson & Toomer Fertilizer Company, Jacksonville, Fla.

Woods, F. J. and L. P., Tampa, Fla.

Wray, Floyd L., Ft. Lauderdale, Fla.

Zipperer, J. O., Ft. Myers, Fla.

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NIGHT TRIP TO PHOSPHATE OPERATIONS

On the evening of June 21 a considerable number of members who had registered for the meetings went for a night tour of several of the local phosphate plants in the immediate neighborhood of Mulberry.

This trip was arranged for by Mr. Frank Holland, Manager, Florida Agricultural Research Institute and Mr. Vincent Souchelli, Director of Research, Davidson Chemical Company of Baltimore and Mulberry.

The cordial cooperation of the management of the several mills was greatly appreciated and exceedingly helpful in giving those on the tour a really good view of the colossal scale upon which these phosphate operations are conducted in Florida.

DEDICATION OF PROCEEDINGS VOLUME X

In the course of developing the program covered by Volume X an earnest effort was made to bring together in summary form the outstanding results that have been accomplished during the past quarter century through the use of certain of the so-called trace or minor elements in the improvement of health and growth in both plants and animals. The important relationship of human health to these factors was not included in this program as it was in the first symposium in 1940 (Proc. Vol. II) since this would have made it much too ponderous for the time allotted. Perhaps this can be the subject of a further and separate review in the near future.

In any event the Executive Committee of the Society is pleased with the results of its efforts and proud of the many excellent contributions from all parts of the United States and many parts of the world that are included in this report. The members of the Committee are no less proud of this opportunity to dedicate this volume to the fine group of workers who have so graciously accepted Honorary Life Membership in the Society on the occasion of this, its Tenth Annual Meeting. Each and every one of these men have made notable contributions to soil or plant science or to some phase of animal health as related thereto. No welcome could be more hearty or sincere than that which we now extend to them as full-fledged members of our group.

Dr. Selman A. Waksman, New Brunswick, N. J.

Dr. Charles F. Kettering, Dayton, O.

Sir John Russell, Campsfield Wood, England

Dr. M. F. Miller, Columbia, Mo.

Dr. F. J. Alway, St. Paul, Minn.

Dr. S. N. Winogradsky, Pasteur Institute, France

Dr. Oswald Schreiner, Chevy Chase, Md.

Dr. W. P. Kelley, Berkley, Calif.

Dr. D. J. Hissink, Bussum, Holland

Dr. Charles E. Millar, East Lansing, Michigan

Dr. John G. DuPuis, M.D., Our Country Doctor, Miami, Florida

SELMAN A. WAKSMAN

SELMAN A. WAKSMAN

Dr. Waksman was born July 2, 1888, in Priluka, a small town in the Ukraine, Russia. His parents were Jacob and Fradia (London) Waksman. He received his early education from private tutors. After graduating in 1910 from the Fifth Gymnasium in Odessa, he left for the United States.

He entered the College of Agriculture of Rutgers University in 1911

and received his bachelor of science in 1915. He became a naturalized citizen the same year. He then was appointed research assistant in soil microbiology under Dr. J. G. Lipman at the New Jersey Agricultural Experiment Station, and later Research Fellow at the University of California. He obtained a master of science degree from Rutgers University in 1916 and a doctor of philosophy degree from the University of California in 1918, majoring under Prof. H. Brailsford Robertson in Biochemistry.

He received an appointment the same year as microbiologist at the New Jersey Agricultural Experiment Station at New Brunswick, New Jersey, and lecturer in soil microbiology at Rutgers University. He became associate professor in 1925, and in 1930 was made professor. He now heads the Microbiology Department, College of Agriculture and Experiment Station, Rutgers University and has recently been made Director of the New Institute of Microbiology.

In 1931, he was invited to organize a division of marine bacteriology at the newly established Woods Hole Oceanographic Institution and was appointed marine bacteriologist of that institution, of which he was later made a trustee.

He is a member, honorary member, or fellow of a number of scientific societies in this country and abroad (Germany, India, Russia, Sweden, Mexico, France, Brazil, Spain). Among the American Societies to which he belongs are the Society of American Bacteriologists, of which he is a former president, the National Academy of Sciences, and the Soil Science Society of Florida of which he is a Charter member. He won the Nitrate of Soda Nitrogen Research Award in 1929, was president of Commission III on Soil Microbiology of the International Society of Soil Science (1927-1935), and was elected as corresponding member of the French Academy of Sciences in 1937. He is also a member of Phi Beta Kappa and of Sigma Xi being President of the Rutgers Chapter of the latter organization.

In the summers of 1946 and 1947, Dr. Waksman lectured before scientific groups in Europe and was given an honorary degree of doctor of medicine by the University of Liege in Belgium. He holds also honorary degrees of doctor of science, awarded to him by Rutgers in 1942, by Princeton University in 1947, and University of Madrid in 1950; also an honorary degree of doctor of laws from Yeshiva University, New York, in 1948.

Dr. Waksman's work in his field has been recognized by numerous scientific and other societies in recent years. He received the Passano Foundation Award in 1947; the Emil Christian Hansen medal and award from the Carlsberg Laboratories in Denmark the same year; the New Jersey Agricultural Society medal; the Albert and Mary Lasker Award by the American Public Health Association, and the Amory Award by the American Academy of Arts & Sciences, all in 1948, and many others.

He has published more than 300 scientific papers, and has written, alone or with others, eight books. Among these are "Enzymes," 1926; "Principles of Soil Microbiology," 1927, 1932; "The Soil and the Microbe," 1932; "Humus," 1936, 1938; "Microbial Antagonisms and Antibiotic Substances," 1945, 1947, and "The Literature on Streptomycin, 1944-1948," 1948; "Actinomycetes," 1950. Another work, edited by Dr. Waksman, is "Streptomycin—Nature and Practical Applications."

CHARLES FRANKLIN KETTERING

CHARLES FRANKLIN KETTERING

Charles Franklin Kettering, Vice-President and Research Consultant of General Motors Corporation, was born on a farm near Loudonville, Ohio, August 29, 1876. He was educated in the county district school, Wooster College, and Ohio State University, graduating in 1904 with the degree EE in ME. He was elected to the honorary fraternities Sigma Xi and Tau Beta Pi.

Following his collegiate work, Dr. Kettering became designer and in-

ventor for the National Cash Register Company, remaining with that organization for five years. He was inventor of the electric cash register, the telephonic credit system, and numerous improvements in accounting and calculating machinery.

In 1909, he became associated with Edward A. Deeds in the organization of the Dayton Engineering Laboratories Company (Delco) for the purpose of developing electrical starting, lighting, and ignition apparatus which he had invented. His invention of the Delco-Light farm electrification system was also completed during this period.

In 1916, he established a private research laboratory which was taken over in 1920 by General Motors and in 1925 moved to Detroit as the Research Laboratories Division of General Motors Corporation. The latter organization, operating under Dr. Kettering's supervision, has been responsible for a large number of important contributions to automotive transportation, including Ethyl gasoline, Duco lacquer, crankcase ventilation, and others.

Another of Dr. Kettering's developments was the two-cycle Diesel engine which has found wide application in the railway and industrial fields. His most recent work has been concerned with high-compression engines for automobiles. In June, 1947, he announced the development of a gasoline engine of 12.5 to 1 compression ratio, giving 35 to 40 per cent better fuel economy than conventional engines. He is the recipient of 174 patents on automotive and related inventions.

Dr. Kettering's widespread interests have led him into many other technical fields. He is the inventor of a fever machine which has proved effective in the treatment of several heretofore incurable diseases.

For most of his life, Dr. Kettering has been actively interested in photosynthesis and the problems related to improvement of soils and agriculture in general. In 1929, he established the Charles F. Kettering Foundation which has carried on research in photosynthesis, cancer, and venereal disease treatment. He has actively supported Soil Conservation and Soil Research, particularly in the field of the use of trace elements.

In addition to his association with General Motors, Dr. Kettering is a Director of the National Cash Register Company, the Flexible Company, and the Mead Corporation. He is Chairman of the Winters National Bank & Trust Company. During World War II, he was Chairman of the National Inventors Council and the National Patent Planning Commission. He is a Trustee of Ohio State University.

Noteworthy among the honors that have come to him are the Sullivant Medal, the John Scott Memorial Award, the Franklin Gold Medal, the Gold Key of the American Congress of Physical Therapy, the Honor Medal Award of the A.S.M.E., and the John Fritz Medal Award. He is the recipient of honorary degrees from 21 different universities and is an honorary fellow of the National Academy of Sciences. He is Past-President of the American Association for the Advancement of Science and the Society of Automotive Engineers.

While Dr. Kettering's accomplishments in various fields of science and research have won him many honors and degrees, he esteems most highly the tag which his fellow workers hung on him years ago and which has clung to him ever since—"Boss Ket."

EDWARD JOHN RUSSELL

EDWARD JOHN RUSSELL

(England)

Sir John Russell was born in 1872. He was trained at the Universities of Wales and Manchester, where his chief interest was in Chemistry. His first scientific appointment, in 1897, was as lecturer in Chemistry at Manchester. In 1901 he moved to the Agricultural College, Wye, as head of the Chemical Department. In 1907 he was appointed Soil Chemist at Rothamsted Experimental Station, and five years later, on the resignation of Sir Daniel Hall, he became Director, a post which he held until his retirement in 1943, soon after the Station celebrated its centenary.

His research work has been mainly concerned with soil fertility, at first on the microbiological aspects of the subject and later on the effect of fertilizers on yield, composition and quality of crops.

Of his many publications, the most widely known is his textbook "Soil Conditions and Plant Growth," which has passed through seven editions and has been translated into many languages.

He was elected a Fellow of the Royal Society in 1917, and is an honorary member of many foreign learned societies. In recognition of his services in the food production campaign during the 1914-18 war he received the Order of the British Empire in 1918, and was knighted in 1922. He has been President of the International Society of Soil Science, and in 1949 was President of the British Association for the Advancement of Science, the first agricultural scientist to be so honoured.

Sir John has travelled widely, especially in the countries of the British Empire, and has an extensive first-hand knowledge of the problems of crop production in many parts of the world. Since his retirement, he has continued his writing and traveling, though this was interrupted by a serious illness in 1944 from which he has happily made a remarkable recovery. His present interest is mainly in the problem of providing an adequate world food supply. As his Presidential Address to the British Association shows, he takes an optimistic view of this, and is confident that scientific research, if properly applied, can find a solution.

MERRITT FINLEY MILLER

MERRITT FINLEY MILLER

Dr. Miller was born in Grove City, Ohio, on July 7, 1875 where he was reared on a farm. His parents were E. Ed and Elizabeth (Demorest) Miller. He received his early education in a typical one-room country school of that time, and later did preparatory work at Ohio Wesleyan University.

In 1900 Dr. Miller completed his B.S.A. degree at Ohio State University, and in 1901 took his M.S.A. degree at Cornell. He studied abroad in Europe at two different times, 1910-1911 at the University of Gottingen, and 1933-1934 at the University of Munich. He received the honorary degree of Doctor of Agriculture from Kansas State College in 1938.

During 1901-1902 Dr. Miller served as Assistant in the Federal Soil Survey, and in December 1902 he married Alice G. Thompson. Many years later, December 1914, he married Grace Ernst. To these unions were born three sons and one daughter, Edward Ernst, Elizabeth Marie, Robert Demorest and Daniel Weber.

Dr. Miller served as Instructor in Agronomy at Ohio State University in 1902-1903, and as Professor of Agronomy at the University of Missouri from 1904 to 1914. From 1914 to 1938 he was Professor of Soils and Chairman of the Department of Soils, and simultaneously served as Assistant Dean of the College of Agriculture from 1929 to 1938. In 1938 he was made Dean of the College of Agriculture at the University of Missouri, in which position he served in a most distinguished manner until his retirement in 1945. He then became Dean Emeritus of the College, Director Emeritus of the Experiment Station and Professor Emeritus of Soils, in which capacities he has continued his interest in the work of the Institution in a most active way. This has expressed itself in a most permanent and beneficial way by the frequent scientific papers and bulletins which he has published and is publishing during this period.

Dean Miller's principal interests have been in the field of soil fertility and erosion; field classification of soils, and factors affecting the nitrogen and carbon levels in soils. His contributions in his chosen field have been numerous and important, perhaps none moreso, however, than those to the state and national program of soil conservation that has made so much progress during the past quarter century.

Professor Miller is a member of many active and honorary societies and organizations, including: Alpha Zeta; Gamma Sigma Delta; Sigma Xi; American Society of Agronomy (President 1923); Soil Science Society of America; International Society of Soil Science; and the American Association for the Advancement of Science (Chairman, Section O).

FREDERICK J. ALWAY

FREDERICK JAMES ALWAY

Dr. Alway was born May 28, 1874 in Waterford, Ontario, and received his early training in Canadian schools. In 1894 he received his B.A. degree from the University of Toronto, and in 1897 his Ph.D. degree from the University of Heidelberg.

From 1898 to 1906 Dr. Alway was professor of Chemistry at Nebraska Wesleyan University, during which period he was particularly interested in research on the reduction of nitro compounds; hydroxylamino—and nitroso compounds and in the soils of the Northern Steppes. From 1906 to 1913 he was Professor of Agricultural Chemistry at the University of Nebraska, during which period his research interests were largely in the bleaching of flour; prairie soils; soil humus; soil moisture; and dry farming.

From 1913 to 1942 Dr. Alway was Professor of Soil Chemistry and Chief of the Division of Soils in the Agricultural Experiment Station at the University of Minnesota. During this period his research interest was largely in glacial, peat and sandy soils; phosphates; the soil requirements of alfalfa; forest soil characteristics and the contributions of sulfur to the soil from the air. In this latter work, Dr. Alway did much in recreating scientific interest in sulfur as an essential element in plant growth when he referred to it in one of his national lectures as "the forgotten element" and, thus, gave much impetus to its further study.

Dr. Alway was a member of the Fertilizer Sub-Committee of the National Research Council; the A.A.F.; the American Chemical Society; American Soil Survey Association (President 1923); American Association for the Advancement of Science; American Society of Agronomy (President 1940); Swedish Peat Society.

At the time of his retirement from active duty in 1942 Dr. Alway was appointed Professor Emeritus of Soil Chemistry and has continued his residence in St. Paul at 1386 Grantham Street since that time.

SERGEI NIKOLAEVITCH WINOGRADSKY

(France)

Dr. Winogradsky was born on September 1, 1856, in the city of Kiev, heart of the Ukraine region, Russia.

It will not be possible, of course, to review in detail Dr. Winogradsky's training, his difficult experiences due to his several moves to foreign countries on three different occasions (Germany, Switzerland, France) due to war, or for other disturbing reasons, and his remarkable life achievements even under these difficult conditions. His mature life, however, according to a remarkably complete and carefully written biographical sketch pre-

pared by Dr. S. A. Waksman on the occasion of Dr. Winogradsky's ninetieth birthday, and published in Soil Science Volume 62, pp. 197-226, 1946, might well be divided into 7 important periods, as follows:

1. *The first St. Petersburg period* (1881-1884), when his interest in science matured. Though this may be considered as still a period of intensive training, Winogradsky began and completed his first scientific problem, which proved to be highly successful (work with wine yeast, *Mycoderma vini* Desm). During this period, he worked in the laboratory of plant physiology of the university.

2. *The Strassburg period* (1885-1888). Here he carried out his first investigations on the autotrophic bacteria. The problems dealing with the sulfur and iron bacteria were begun and completed at the botanical laboratory of the university under deBary.

3. *The Zurich period* (1888-1891). The study of the organisms concerned in the process of nitrification was begun and nearly completed at the agricultural faculty of the polytechnicum and at the hygienic laboratory of the university.

4. *The second St. Petersburg period* (1891-1905). This began with research activities and ended in administration work, the latter being largely responsible for his subsequent temporary retirement from both. The most important research problems dating to this period concerned the fixation of atmospheric nitrogen and the retting of flax. This work was done at the Institute of Experimental Medicine.

5. *The period of transition and rest* (1905-1922). These 17 years were spent by Winogradsky on his estates in the Ukraine, away from scientific work. As a result of political upheaval following the World War and the revolution, he was eventually forced to leave his native country forever. After a few months spent in Jugoslavia, he finally arrived at the Pasteur Institute in France.

6. *The active Brie-Comte-Robert period* (1922-1940), which signalized a return to scientific work. The problems considered were largely connected with the broad aspects of soil microbiology. This work was done in the Division of Agricultural Microbiology of the Pasteur Institute.

7. *The period of forced retirement* (1940- -), following the invasion of France.

The name of Winogradsky has assumed a permanent place in bacteriology through the profound influence of his investigations upon the subsequent development of many important branches of the science. As a result of the brilliant and epoch-making investigations of Louis Pasteur, Ferdinand Cohn, and Robert Koch, bacteriology developed rapidly from a mere biological curiosity into a science of great practical importance, with numerous ramifications, stretching into the domains of medicine, agriculture, industry and certain arts.

Dr. Winogradsky is still living at Brie-Comte-Robert near Paris at the age of 94. Under date of 1949 there appeared a large book entitled "Microbiology of the Soil" (MICROBIOLOGIE DU SOL) containing 861 pages which gives a very good idea of the remarkable life he has lived, filled with accomplishments, many of them developed under very great difficulties but, above all, a life that has been replete with devotion to his science.

WALTER PEARSON KELLEY

WALTER PEARSON KELLEY

Dr. Kelley was born February 19, 1878 in Franklin, Kentucky. He received his B.S. degree from the University of Kentucky in 1904; his M.S. from Purdue University in 1907; and his Ph.D. in 1912 from the University of California, which University, in June of 1950, also awarded him the honorary degree of LLD.

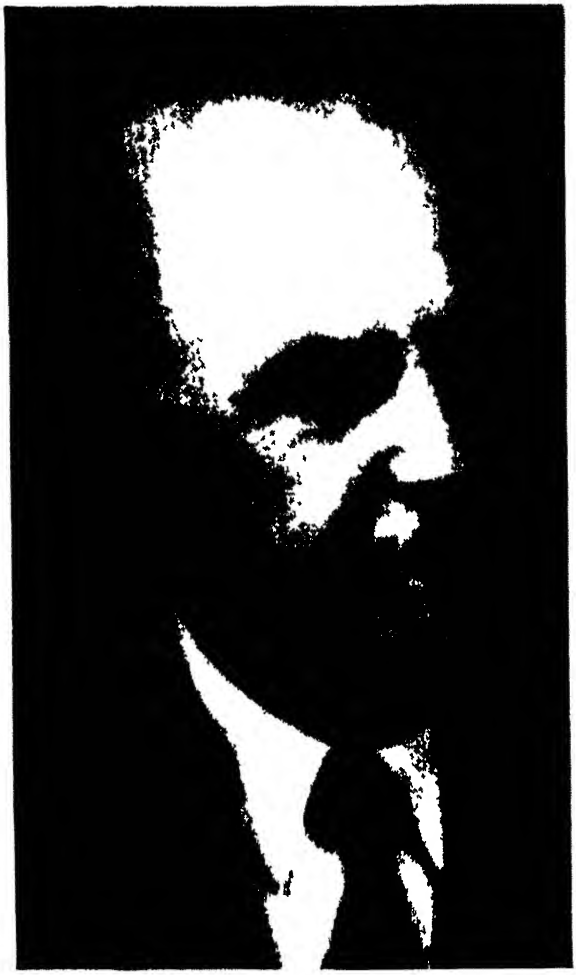
From 1905 to 1908 Dr. Kelley was Assistant Chemist at the Purdue Experiment Station, and Chemist at the Hawaiian Experiment Station from 1908 to 1914. He then became Agricultural Chemist at the Citrus Experiment Station, Riverside, California. In 1939 he went to Berkeley as Soil Chemist and Head of the Division of Soils in the University, in which position he continued until his retirement in 1948.

Dr. Kelley's principal interest in research has centered around nitrogen utilization by rice; effect of heat on soils; composition of Hawaiian soils; forms of nitrogen in soils; nitrification; effect of boron on citrus and walnut trees; cation exchange; alkali soils; crystallinity of soil colloids; crystal structure in relation to base exchange; clay minerals of soils; and the interrelationships of soil science and geology.

According to one of his close associates, "Dr. Kelley's contribution to our fundamental knowledge of soil chemistry has been extremely important. In 1931, with W. H. Dore and S. M. Brown, he was able to show from X-ray diffraction studies that soil colloids are crystalline and not amorphous as was thought until that time. This discovery gave great impetus to the study of clay chemistry and as a result of this many of the soil minerals have been separated out and their chemistry studied. Much of this latter work has been carried out by Dr. Kelley and is described in a long series of papers in the journals of soil science and mineralogy. The work is also reported by him in an American Chemical Society Monograph on Base Exchange."

Dr. Kelley also has achieved an international reputation for his work on alkali soils. This work was begun in 1920 and has been reported in some twenty odd papers, and also in a monograph on alkali soils, which he has just completed. In these researches, reclamation methods were developed which are now being employed throughout the world in connection with this serious problem of irrigated agriculture.

Among his many affiliations with scientific and other organizations are included American Association for the Advancement of Science; American Chemical Society; Fellow of American Society of Agronomy (President 1930); Soil Science Society of America; International Society of Soil Science; Geophysical Union and Western Society of Soil Science.



OSWALD SCHREINER

Dr. Schreiner was Chief of Soil Fertility Investigations in the U.S. Department of Agriculture for more than 40 years. He is now retired but still connected with the department as collaborator.

The research work on the fundamental principles of soil fertility, especially those relating to the chemistry and biochemistry of soil organic matter or humus and to its functions in promoting or hindering plant development, won for Dr. Schreiner a prominent place of leadership among soil scientists and agronomists at home and abroad. To the laboratory under his direction belongs the credit for the chemical discovery, physical separation and plant physiological study of over fifty new soil compounds, which has materially altered the fundamental conception of

soil humus and its formation and transformation by plants and microorganisms and its effects and functions in crop production. He is the inventor of the Schreiner colorimeter and designer of colorimetric methods, which, on account of their great applicability to various lines of soil and plant research have been widely used for the determination of small quantities of plant nutrients in chemical laboratories in this country and abroad, as was also his triangle system for studying and determining fertilizer requirements of soils and crops under field conditions.

He made a special study of soil fertility and its maintenance, causes of unproductive soils, transformation of humus by biochemical factors, origin of organic constituents in soils and means for the improvement of unproductive soils by fertilizers, manures, crop rotations and the use of special chemicals including some of the minor elements. This field work included the establishment of more than twenty field stations along the Atlantic seaboard from Maine to Florida and in a number of western states, with fertilizer tests made with potatoes, cotton, celery, lettuce, sorghum, sugar beets, sugar cane, corn, clover, pecans, citrus fruits and many other crops.

Dr. Schreiner won a national reputation by his many lectures at agricultural colleges and before farmers' institutes and clubs and scientific societies. Many honors have been awarded him for his chemical and agricultural researches, three medals for proficiency in chemistry and other sciences while attending the University of Maryland, and while attending the University of Wisconsin he was elected to the honorary society of Phi Beta Kappa and Sigma Xi and was awarded the Ebert prize for his researches on the chemistry of the volatile oil hydrocarbons. The Franklin Institute awarded him its Longstoreth medal of merit "for important researches in agricultural chemistry."

As Chairman of the Organizing Committee he contributed greatly to the success of the International Soil Science Congress in Washington in 1929. He was elected Fellow in the American Association for the Advancement of Science and the American Society of Agronomy and is a member of the American Chemical Society, the American Society of Biological Chemists, Washington Academy of Sciences, Botanical Society of America, International Society of Soil Science, International Society of Sugar Cane Technologists, the Cosmos Club, and the Association of Official Agricultural Chemists of which he is a past president and many other societies.

Dr. Schreiner's work on soils and fertilizers has received national and international recognition. In this connection he has traveled extensively throughout the United States and many foreign countries, including England, Scotland and Wales, Germany, France, Holland and Belgium, Japan, China, Philippines, Malay States, Sumatra, Java, Bali, as well as Cuba, Puerto Rica and Hawaii. He investigated the potash hunger diseases of potatoes and cotton and first described the characteristic foliage symptoms and reactions during the first World War, which work later developed into that long series of soil and fertilizer studies known as the "hunger symptoms of crops" and led to the many plant and soil test methods for the determination of plant nutrient deficiencies and fertilizer requirements of crops.

DAVID JACOBUS HISSINK

DAVID JACOBUS HISSINK

(Holland)

Dr. Hissink was born October 22, 1874 in Kampen, Holland. He was trained in the local schools and in the "Gymnasium" until 1893 when he entered the University of Amsterdam, where he continued his studies until 1899, when he received his doctor's degree. The years 1900 to 1903 were spent in the Dutch East Indies.

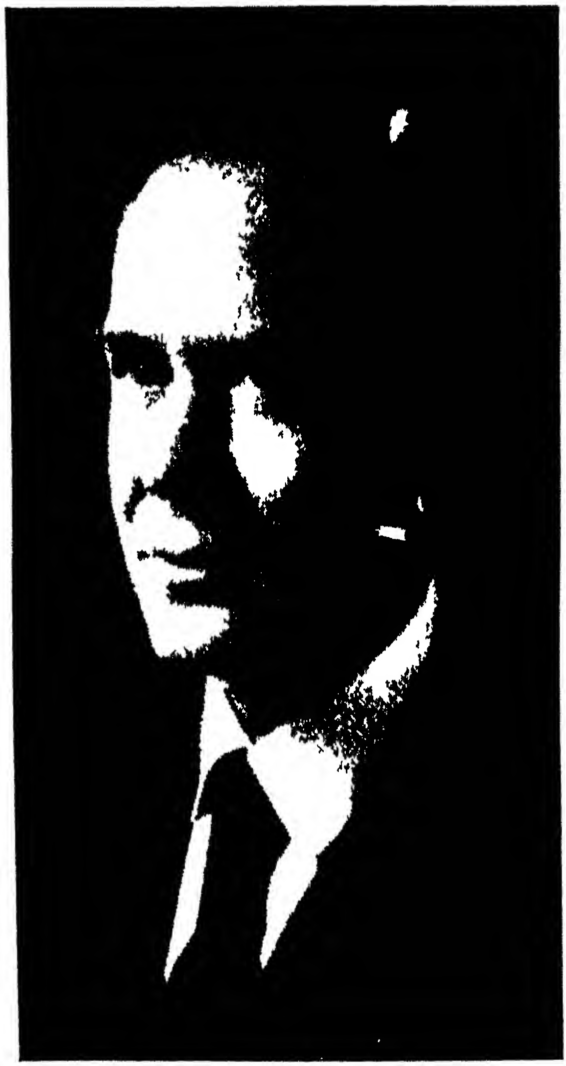
In March of 1903, Dr. Hissink went to the Agricultural Experiment Station at Goes. and in 1904 became the Director of that Station in which capacity he continued until 1907. From April of 1907 to May of 1916 he served as Director of the Agricultural Experiment Station at Wageningen. From May of 1916 to May of 1926 he served as Director of the Soil Science Division of the Agricultural Experiment Station in Groningen, and in May of 1926 he became Director of the Soil Science Institute in that same city, in which capacity he served until his retirement in 1939 at the age of 65.

Although an extremely energetic and effective worker in the International Society of Soil Science and many other public service organizations, Dr. Hissink found time for a very considerable amount of writing, in addition to the extensive administrative duties to which his position obligated him all the way along. His list of publications in Dutch and other journals is very impressive, numbering nearly 350 on a wide variety of subjects largely relating to soil science.

Doubtless the work for which Dr. Hissink is best known, and for which he will be long remembered in a personal as well as professional way, is his development and application of the principal of base exchange. His most important application of this principal was in the removal of the salt from the heavy clay soils formerly occupied by the sea in the extensive reclamation areas for which Holland is famous. What Dr. Hissink did, in its simplest terms, was to convert the highly plastic, impervious sodium clays, practically unleachable in their natural state, to comparatively pervious, leachable calcium clays through the use of gypsum.

"Basenaustausch" is the term in German and Dutch literature for which Dr. Hissing is probably more responsible than any other one man, at least insofar as it relates to soil science and finds both practical and scientific applications, therein.

Dr. Hissink is a member of many National and International societies and has received many honors from foreign governments and more than once from the Dutch Government, the last being a Knighthood bestowed at the time of his retirement in 1939. He continues in a quiet life at s'Jacoblaan 37, Bussum, Holland, whence he keeps a keen contact with the societies and journals he has helped to build, and still is an active adviser in the research work on the soils of the Zuiderzee.



CHARLES ERNEST MILLAR

CHARLES ERNEST MILLAR

Dr. Millar was born on a farm in Coles County, Illinois, June 23, 1885. He attended high school in Mattoon, Illinois, and received his B.S. and M.S. (in chemistry) from the University of Illinois in 1909 and 1911 respectively. Later he received his B.S. in Agriculture from Kansas State College in 1915, and his Ph.D. from the University of Wisconsin in 1923.

He was Assistant in Chemistry at Kansas State College from 1910-1913; Assistant in Agronomy, 1913-1914, and Instructor in Agronomy, 1914-1915; Assistant Professor in Soils at Michigan State College, 1915-1918; Associate Professor, 1918-1925; and Professor, 1925-1930. Dr. Millar became Head of the Department of Soils at Michigan State College in 1930 and continued in this position until his retirement in 1950, since which time he has been Professor Emeritus of Soils.

Dr. Millar is a member of Phi Lambda Upsilon, Alpha Zeta, Phi Kappa Phi, Phi Sigma and Sigma Xi. He was also awarded the Diploma of Merit by the State Board of Agriculture, governing body of Michigan State College, in appreciation of his long and effective service to Michigan agriculture. He is also a Fellow of the American Society for the Advancement of Science (Secretary of Section O—Agriculture) and Fellow of the American Society of Agronomy (Chairman Soils Section, 1935).

As his principal fields of interest, Dr. Millar was always found spending most of his spare time with his students and in the pursuit of special problems in his chosen field of soil fertility, especially as it relates to crop production. During his teaching career time was found by Millar for two books—*Soils and Soil Management*, by Webb Publishing Company, and *Fundamentals of Soil Science* (with Dr. Turk) by John Wiley and Sons.

JOHN GORDON DUPUIS, M.D.

JOHN GORDON DUPUIS, M.D.

(Our Country Doctor)

Dr. DuPuis was born in Alachua County, Florida, September 25, 1875. His parents were John Samuel and Mary Lohman DuPuis. In January 1899 he married Katherine Elizabeth Beyer in Paducah, Kentucky. To this union one son was born, John G. DuPuis, Jr.

Dr. DuPuis received his M.D. degree from the University of Louisville in June 1898, only shortly previous to his coming to Florida. He also has studied in the New York Post Graduate Medical School.

For more than 50 years Dr. DuPuis has served Miami and Dade County as a Country Doctor, in all the hallowed spirit and traditions of service that the term implies. It is because of this long, faithful and courageous service that the Society has requested his permission to include him as OUR Country Doctor among those whom we have elected to honorary life membership on the occasion of the Tenth Annual Meeting.

It would be very difficult for most people to imagine what Dr. DuPuis saw when he got off the train on October 28, 1898 at Lemon City, at that time scarcely an outpost of the Village of Miami which was still 5 miles farther south; or to realize that the small shack in which he started his practice of medicine shortly following his arrival stood very near the busy corner (6045 N.E. Second Avenue) on which his office now stands.

Along with the weary hours and busy routine of his medical work, Dr. DuPuis always found time, somehow, for a great many other public service activities of the type that always prove themselves indispensable elements in the development of a young pioneer community of the type in which he found himself, and of which he proceeded to make himself a truly integral part. In the first place, he gave much time to the development of church facilities in this new area and, through the years, took an active and frequently an aggressive part in a wide variety of civic organizations for the highly important part they always play in community progress. These included work on/or with church boards; school boards; drainage boards; Chamber of Commerce; State and County Medical Associations; Farm Bureau; Dairy Association; President, Dutch Belted Cattle Association of America; and many other associations.

Likewise, Dr. DuPuis very early decided that one of the most outstanding needs for children in this pioneer community was a better and more abundant milk supply. From this very humble beginning, which first started with his own family cow, there gradually emerged the great White Belt Dairy now employing hundreds of people, and which is still serving the Miami area as one of the largest and most modern individually owned dairies in the Southeast.

Thus, Dr. DuPuis has served this Florida community not only through its first, and only, outbreak of yellow fever and seventeen hurricanes, but all of the people all of the time, regardless of race, religion or financial circumstances, through more than half a century. He is now the only charter member of the Dade County Medical Association who is still active.

His great love of plants doubtless brings Dr. DuPuis closer to the soil than anything else. In his intense hobby for gardening, he accomplishes most remarkable things in the short time he is able to find for this work each day, especially in the field of tropical plants. His decided interest in plant health thus gives him a quick appreciation of the direct relationship of plant composition and health to the fertility level of the soil on the one hand and, on the other, to health and well being of animals, as well as men, who must live on them. Thus, through the channels of his medical wisdom, fortified by such an understanding, the relationship of soil to health has been brought by him to the attention of many people, not only in behalf of their well being and that of their immediate families, but for the health and well being of animals as well.

Institut Pasteur

BRIE-COMTE-ROBERT

(SEINE-&-MARNE)

Brie-Comte-Robert, July 29-th, 1950

Dr. R. V. ALLISON, Secretary-Treasurer,
The Soil Science Society of Florida,
BELLE GLADE, Florida,
U. S. AMERICA.

Dear Dr. Allison,

Your letter of June 28-th I have duly received, and I am very touched by the honour the Soil Society of Florida has done me in electing me to an honourary life membership.

The photographe you ask for, I am mailing you, under separate cover, by ordinary mail.

Meanwhile, the copy of Vol. VIII of the Proceedings has also reached me, for which I thank you very much.

With my kindest regards and best wishes,

I remain,

Yours sincerely,

S. Winogradsky.

Department of Microbiology
Agricultural Experiment Station
New Brunswick, N. J.

. . . We have just returned (from Europe) and I hasten to . . . tell you how highly honored I feel to have been elected to Honorary Life Membership in the Soil Science Society of Florida.

(Signed) Selman A. Waksman,
Microbiologist

Charles F. Kettering Foundation
Dayton, Ohio

Thanks for your kind letter of June 28th. I appreciate being included among the notables.

(Signed) Ket
C. F. Kettering

Campsfield Wood
Woodstock, Oxon., England

Your letter . . . informing me that the Soil Science Society of Florida had elected me to Honorary Life Membership gave me very great pleasure, and I am indeed proud of the honor they have conferred upon me.

(Signed) E. J. Russell

514 High Street
Columbia, Mo.

I truly appreciate the honor the Society is bestowing on me although I do not feel that it is deserved.

(Signed) M. F. Miller

1386 Grantham Street
St. Paul, Minn.

I greatly appreciate the honor of the action taken by the Executive Committee in electing me to Honorary Life Membership in the Society.

(Signed) F. J. Alway

College of Agriculture
Division of Soils
Berkley, California

I am of course happy to accept Honorary Life Membership in the Soil Science Society of Florida. Indeed I am grateful for this honor.

(Signed) W. P. Kelley

21 Primrose Drive
Chevy Chase 15, Md.

I feel greatly honored by . . . my election to Honorary Life Membership in the Soil Science Society of Florida.

(Signed) Oswald Schreiner

Burgemeester's Jacobeaan 37
Bussum, Holland

The Soil Science Society may be sure that I feel it is a great honor that my name was included in the group of Soil Scientists elected to Honorary Life Membership . . . and it is a great pleasure for me to accept this honor.

(Signed) D. J. Hissink

Department of Soil Science
Michigan State College
East Lansing, Mich.

This action is indeed an honor, and I greatly appreciate being included among the first ten men to receive this distinction from your Society.

(Signed) C. E. Millar

6043 N. E. 2nd Avenue
Miami 38, Florida

I wish to express my appreciation to the Executive Committee of the Society. I consider it a great honor to be included in the group which the Society has elected to Honorary Life Membership at its tenth annual meeting.

(Signed) J. G. DuPuis, M.D.

EDWARD MACARTHUR REDDING

EDWARD MACARTHUR REDDING

Dr. Redding was born October 27, 1915. He received his B.S. degree in Chemical Engineering at the University of Denver in 1938 and his Sc.D. degree in the same field from Massachusetts Institute of Technology in 1942. During 1941-2 he was engaged in Classified Research (NRDC) at M.I.T. From 1942 to the present time Dr. Redding's activities and accomplishments are listed briefly through the periods in which they fall:

1942-1945 U. S. Navy, Bureau of Aeronautics, Power Plant Design Branch, as a Naval Officer (Lt. Comdr. USNR), was active in coordinating development of turbo-jet and ram-jet engines for the Navy and research on related problems of high temperature alloys and combustion. Received commendation for work from the Secretary of the Navy.

Member, National Advisory Committee for Aeronautics Subcommittee for Combustion and Heat Resisting Alloys; Co-author of report by Jet Propelled Missiles Panel, Coordinator of Research and Development U.S. Navy.

1946-1948 North American Aviation, Inc. Aerophysics Laboratory

Co-originator and Assistant Technical Director of the Aerophysics Laboratory, organized to carry out research and development on guided missiles.

Member, National Advisory Committee for Aeronautics Subcommittee for Combustion. Specialized on rocket motor research and development.

1948 Massachusetts Institute of Technology, Research Staff

Participated in an evaluation study and co-author of a report for the Atomic Energy Commission on certain phases of its nuclear power program.

1948 to present Charles F. Kettering Foundation, Director of Research

In charge of coordinating and guiding the research program which is principally in the field of photosynthesis. With the exception of some preliminary laboratory work at the Dayton headquarters, most of the research is carried out by other agencies under contract. These agencies are mostly universities. A small part of the program is devoted to medical research.

Member American Chemical Society, American Institute of Chemical Engineers, Ohio Academy of Science, American Association for the Advancement of Science, Sigma Xi, Phycological Society, Soil Science Society of Florida.

PHOTOSYNTHESIS—A LINK BETWEEN THE SUN AND THE SOIL

Edward M. Redding*

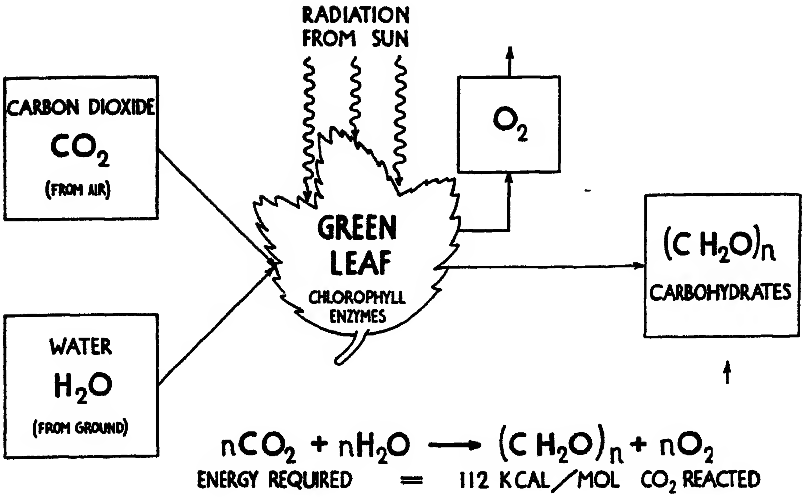
Practically every research worker who talks on the subject of photosynthesis presents a different point of view—his own. There are these many points of view because of the complexity of the problem, the differences in opinion, and the relative lack of success to date in solving the problem. The approach to the problem recently taken by the Charles F. Kettering Foundation is rather unique, but it is believed that tangible results will be forthcoming within a relatively short period.

Mr. Charles F. Kettering established the Foundation in 1929 for the purpose of financing research on photosynthesis and other problems, the solution to which would benefit mankind in general. A photosynthesis research project was started at Antioch College in Yellow Springs, Ohio, under the direction of Dr. O. L. Inman in 1930. This project has continued until the present time and is still operating at about the original level of activity. Until fairly recently, it was the only major project financed by the Foundation. Then, just before World War II, the Fever Therapy machine was developed for the treatment of venereal disease by the Foundation at the Miami Valley Hospital, Dayton, Ohio.

The photosynthesis research group at Antioch College concentrated on the study of chlorophyll, the green pigment in all photosynthesizing plants and which is generally credited with being the agent which absorbs the light energy used in the photosynthesis process. About two years ago, the decision was made to initiate more projects at other institutions and to attack the problem in a somewhat more basic fashion. This line of attack will be explained later.

Perhaps it would be helpful to discuss the more elementary phases of the photosynthesis process at this point. Figure 1 is a simplified picture of the primary photosynthesis reaction. Water and carbon dioxide combine with the addition of energy obtained from sunlight to form carbohydrates and release oxygen gas. This reaction has never been accomplished outside the green leaves of plants. These leaves contain chlorophyll and several other pigments, enzymes (biological catalysts of high molecular weight), inorganic and organic salts, and other materials of unknown function. This simple reaction as shown does not touch upon the important subject of the incorporation of nitrogen into the products of photosynthesis such as the proteins and chlorophyll itself. In general, the nitrogen comes from nitrate or ammonium ions in the plant fluids fed to the leaf, but its incor-

FIGURE I- PRIMARY PHOTOSYNTHESIS REACTION



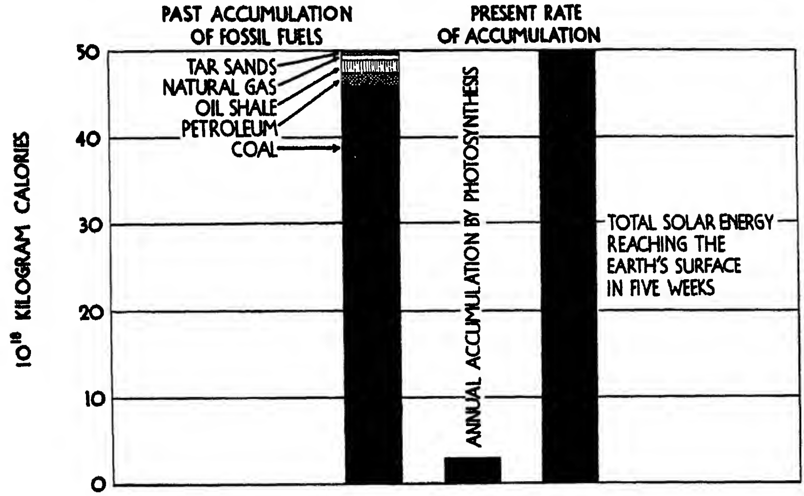
poration into the plant products may or may not be linked to a photochemical reaction.

The photosynthesis process has been a classical subject for investigation for at least 175 years. Generally speaking, in the early days, there was no real objective of the research beyond curiosity as to the workings of this important process and some desire to improve agriculture by increased knowledge of the photosynthesis reaction.

The objective of the Charles F. Kettering Foundation is to gain sufficient knowledge of the mechanism of photosynthesis that an identical or similar process can be developed outside the plant for use in the industrial production of food, fuel, or special chemicals. Our interest lies in the process of solar energy pick-up and conversion to chemical or electrical energy of high potential. The conversion of solar energy to low temperature heat for home heating, etc. does not provide a product capable of producing power and hence is of relatively limited applicability and interest.

Figure 2 shows how very ineffectively the Earth has been able to store the solar radiation incident upon it. The total amount of energy stored in the coal and petroleum in the Earth's crust during the past three billion years is only equivalent to the solar energy reaching the Earth's surface in five weeks! The rest of the incident solar energy has been re-radiated into space as low wave-length infra-red radiation. Some of it, of course, has been picked up temporarily by photosynthesis, and Figure 2 shows that the yearly accumulation of energy by photosynthesis is quite appreciable. However, decay of the plant material

FIGURE 2 - TOTAL RATE OF PHOTOSYNTHESIS ON EARTH

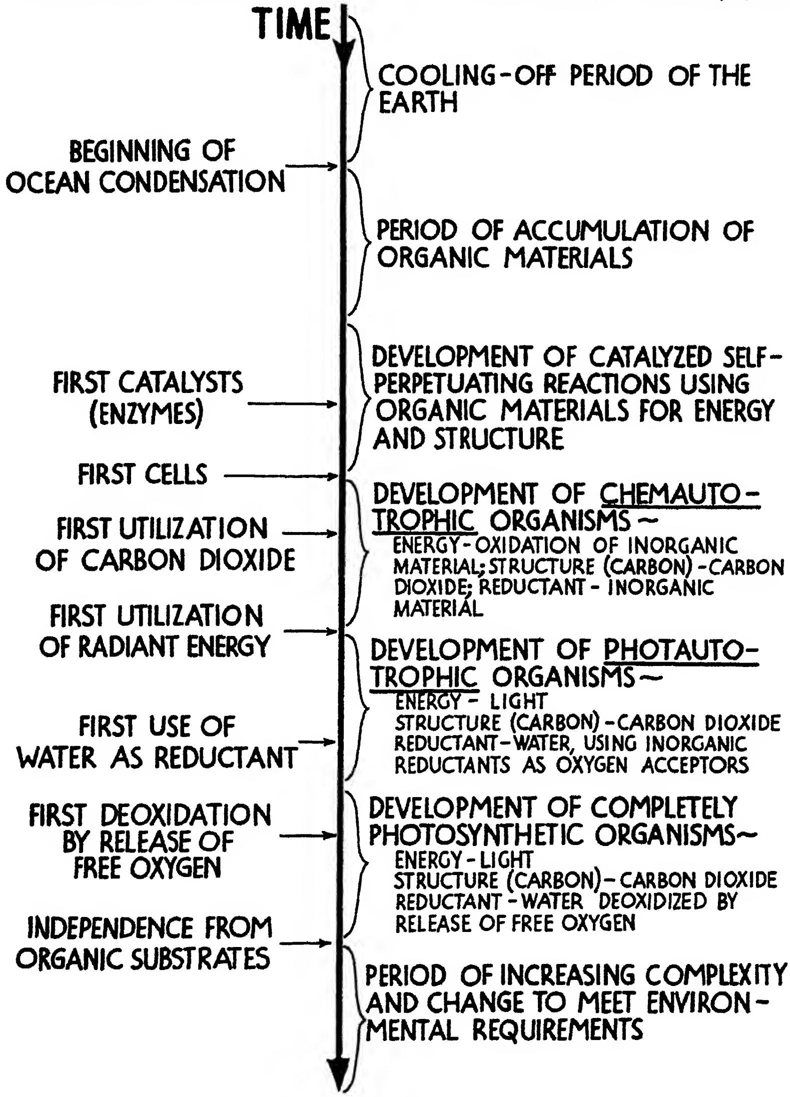


allows this energy to be dissipated except for the infinitesimally small amount retained in the deposits which are being slowly made into peat and coal.

So it is seen that the Earth receives a tremendous amount of energy from the Sun which can be utilized to the extent that we learn how to use it. It is indeed a worthy challenge to the scientist and engineer. An inexhaustible source of energy or fuel is an objective worthy of great effort.

It is true that practically every major researcher in photosynthesis has a somewhat different approach to the problem. The study of chlorophyll has been a popular approach by many including the Kettering Foundation. Some of the most prominent people in the field are engaged in an effort to determine the "quantum efficiency" of photosynthesis,—the number of light quanta required to reduce one molecule of carbon dioxide. During the past five years, some interesting results have been obtained by feeding radioactive carbon-14 labeled carbon dioxide to plants exposed to light, killing the plants, extracting and identifying the intermediate products of photosynthesis. The results have not been as extensive as had been expected in the beginning, but advances have been made. However, no matter how successful the latter approach will turn out to be, little information will be gained as to the nature and mechanism of the most important portion of the process—the photochemical decomposition of water. Most authorities agree that the photosynthesis process can be divided into two separate parts (a) the photo-decomposition of water to release oxygen and form a reducing agent and (b) the reduction of carbon dioxide by the reducing agent without the aid of light. The labeled CO_2 experiments will tend to

FIGURE III – THE DEVELOPMENT OF THE PHOTOSYNTHESIS PROCESS – A POSSIBLE TIME SEQUENCE



clarify the latter phase of the problem, but the photochemical reactions must be investigated in a different way.

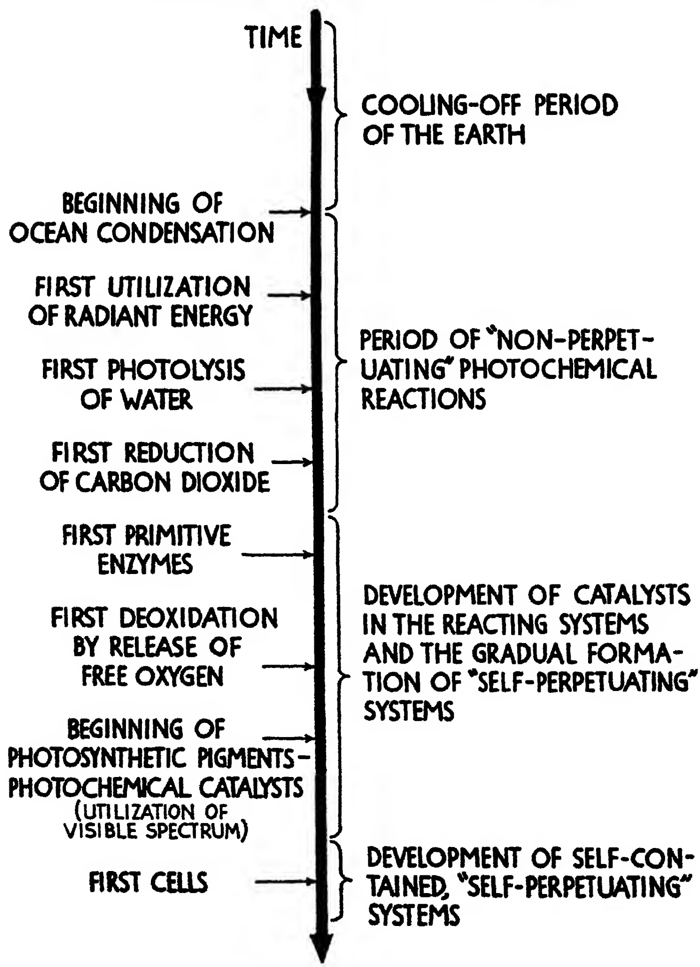
The Charles F. Kettering Foundation program has been recently reorganized to concentrate on the photochemical phase of photosynthesis. Our overall approach to the problem we call the

"prebiological" approach. As far as we know, in its overall aspects it is unique.

Several years ago, Mr. Kettering formulated the basic principles of the "prebiological" approach when he thought about the generally held conviction that the photosynthesis process and apparatus in present-day green plants is the result of evolution from a much simpler process in the very early period of the existance of biological entities. By extending the idea to even earlier time periods, he realized the importance of conditions on the

FIGURE 4 - THE DEVELOPMENT OF THE PHOTOSYNTHESIS PROCESS

AN ALTERNATE POSSIBLE TIME SEQUENCE



Earth and sequence of events leading to the formation of the first biological cells. This period in history he called the "prebiological" period, and the corresponding chemical and physical events he call "prebiological chemistry and physics." A knowledge of the "prebiological" period and of the first part of the subsequent "biological" period would be of immense value in unraveling the photosynthesis tangle. Obviously, an exact knowledge of the prebiological period is impossible, but it does seem possible to use indirect evidence to build up a hypothetical picture which could be very useful, of the prebiological period and its sequence of events. This we are endeavoring to do, with moderate success to date.

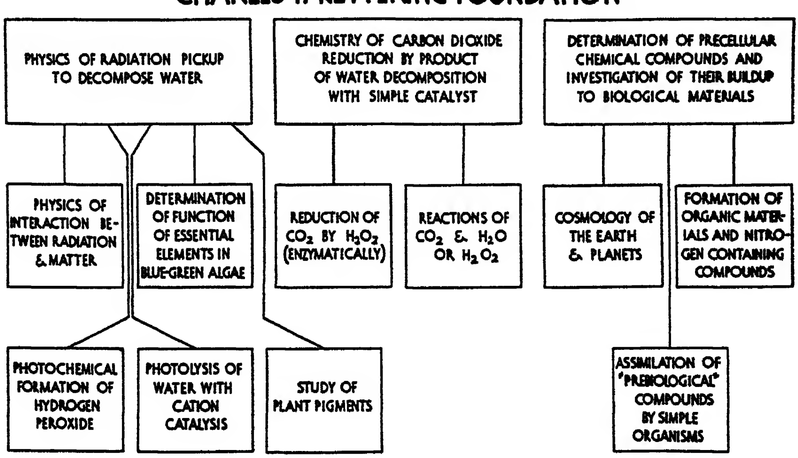
Figure 3 shows a possible time sequence of events by which cells capable of photosynthesis could have been evolved. This particular sequence is a summary of ideas of several authorities and probably represents the feelings of most biologists. It assumes that the utilization of solar energy followed the use of energy from the oxidation of available high energy matter.

Figure 4 shows an alternate time sequence in which it is postulated that the radiation from the sun was the actuating energy from the very beginning and that biological cells using energy from the oxidation of carbon and hydrogen compounds were later developments.

The latter supposition is quite logical in many ways, and we tend to favor it over the former sequence. However, neither sequence may even approximate the actual series of events.

Figure 5 is a summarized chart of the main portions of the Foundation's photosynthesis research program. As can be seen, the program can be divided into three main avenues of attack—the physics of radiation pickup, the chemistry of carbon dioxide

FIGURE 5-OUTLINE OF RESEARCH PROGRAM
CHARLES F. KETTERING FOUNDATION



reduction, and the investigation of prebiological chemistry. The emphasis is on the first category.

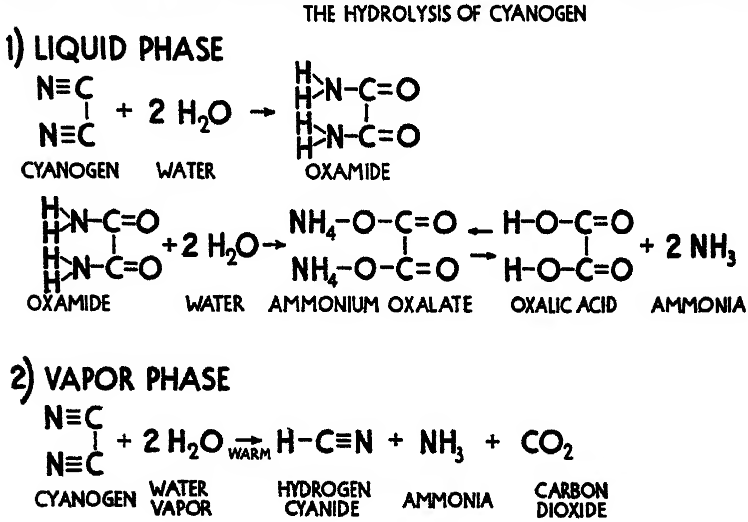
Figure 6 is a list of molecules and compounds that we believe to have been present at the surface of the Earth during "prebiological" times. Only the more obvious materials are placed under the category "definite." Most of the other compounds have been added to our list from literature research and our experi-

FIGURE 6 - PREBIOLOGICAL COMPOUNDS

DEFINITE	PROBABLE	POSSIBLE
H_2O	ACETYLENE	PYROLLE
CO_2	GLYCINE	FORMALDEHYDE
O_2	ALANINE	HYDROCARBON MIXTURES
O_3	CARBON	
N_2	CARBON MONOXIDE	
NH_3	HCN	
H_2	HCNO	
HNO_3	OXALIC ACID	
H_2O_2	FORMIC ACID	
	OXAMIDE	
	"AZULMIC ACID"	
	CYANOGEN	
	UREA	
	METAL CARBIDES	

FIGURE 7 - SOURCES OF PREBIOLOGICAL ORGANIC COMPOUNDS

THE HYDROLYSIS OF CYANOGEN



mental investigations in the Chemistry Department of the Ohio State University.

For instance, there is reason to believe that cyanogen would have been present in the prebiological atmosphere. The hydrolysis of cyanogen yields many biologically interesting substances, a few examples of which are given in Figure 7.

The hydrolysis of metal carbides probably furnished many organic compounds. Figure 8 shows several examples of known

FIGURE 8 – SOURCES OF PREBIOLOGICAL ORGANIC COMPOUNDS

THE HYDROLYSIS OF CARBIDES

1) $Al_4C_3 + 6H_2O \rightarrow 3\,CH_4 + 2Al_2O_3$

ALUMINUM CARBIDE — WATER — METHANE — ALUMINUM OXIDE

2) $3Fe_mC_n + 4m\,H_2O \rightarrow C_{3n}H_{8m} + m\,Fe_3O_4$

IRON CARBIDE — WATER — NAPHTHA — IRON OXIDE

3) $Ca\,C_2 + H_2O \rightarrow HC\equiv CH + CaO$

CALCIUM CARBIDE — WATER — ACETYLENE — CALCIUM OXIDE

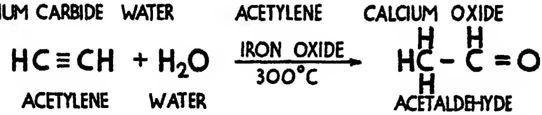
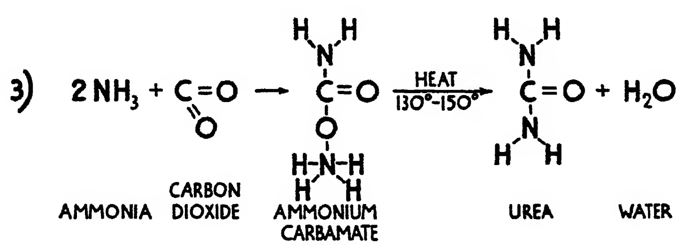


FIGURE 9 – SOURCES OF PREBIOLOGICAL ORGANIC COMPOUNDS

NITRIDES AND NITROGEN



4) $N_2 + O_2 \xrightarrow{\text{LIGHTNING}} 2\,NO$

NITROGEN — OXYGEN — NITRIC OXIDE

$NO + \frac{1}{2}O_2 \longrightarrow NO_2$

NITRIC OXIDE — OXYGEN — NITROGEN DIOXIDE

$3NO_2 + H_2O \longrightarrow 2\,HNO_3 + NO$

NITROGEN DIOXIDE — WATER — NITRIC ACID — NITRIC OXIDE

reactions which could have been involved. The presence of nitrogen containing compounds could be explained by such known reactions shown in Figure 9.

The radiation from the Sun is converted to other forms of energy on the Earth's surface in the four main ways listed in Figure 10. By the evaporation of water, water vapor enters the atmosphere and is carried above the mountains. Rain falls and rivers flow downward toward the sea. By proper placement of dams and powerhouses, some of the potential energy in this water can be converted to useful electrical energy. The use of solar energy for space heating has been mentioned previously. It is possible, but only barely practical under favorable conditions, to use solar energy to heat boilers for steam power generation.

Atmospheric electricity is generated as an indirect result of the solar evaporation of water into clouds. This electric energy cannot be utilized effectively.

By far the largest amount of solar energy conversion takes place in green plants, where water is decomposed in photosynthesis, and the energy thus trapped is used to form plant products such as carbohydrates, fats, and proteins from carbon dioxide. This was the original source of the energy we obtain when we burn coal or petroleum products. Such a process is one we wish to duplicate or improve.

Chlorophyll has been mentioned as the most probable agent of radiation reception in the green plant. It may not be the only one, however. Chlorophyll can be extracted from green leaves or other green portions of plants by organic solvents. Its structure has never been completely confirmed as it has never been synthesized. Figure 11 shows the structure most generally considered correct. However, there is evidence to indicate that chlorophyll

FIGURE 10 – RADIATION FROM THE SUN

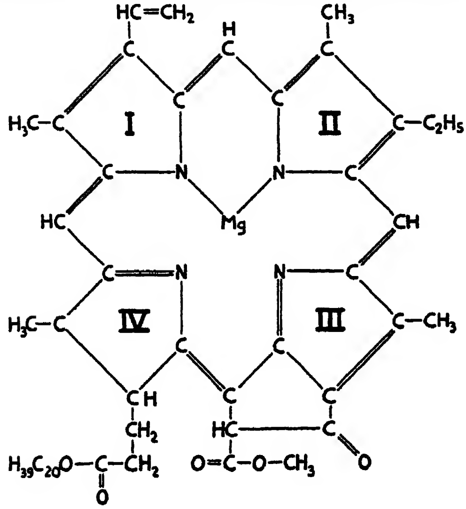
1 – EVAPORATION OF WATER

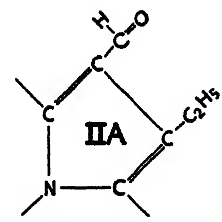
2 – HEATING THROUGH SURFACES

3 – GENERATING ATMOSPHERIC ELECTRICITY

4 – DECOMPOSITION OF WATER (THE BASIS OF PHOTOSYNTHESIS)

FIGURE 11—STRUCTURAL FORMULA FOR CHLOROPHYLL a ($C_{55}H_{72}O_5N_4Mg$)





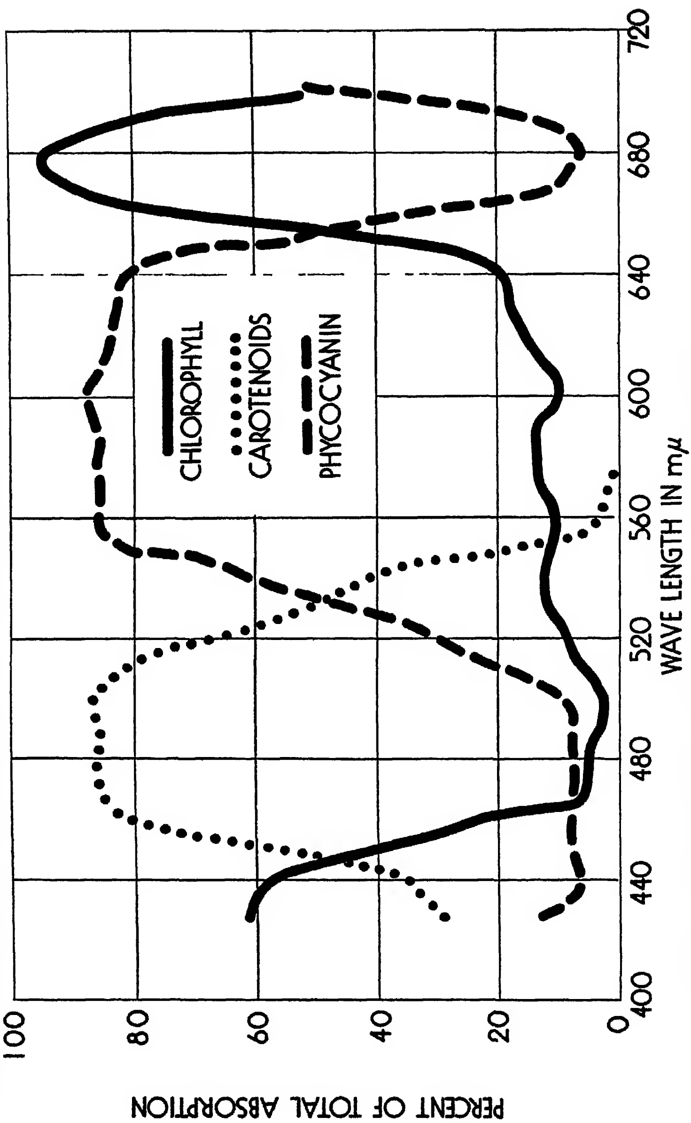
CHLOROPHYLL b

exists in the plant as a complex with protein. It has been shown many times that extracted chlorophyll is unable to produce photosynthesis outside the plant thus tending to confirm the fact that the protein complex is required in the plant for proper functioning.

Chlorophyll is not the only pigment present in photosynthesizing plants. Most plants have 3 or 4 other pigments, depending on the type of plant. For instance, most blue-green algae, simple single cell plants, have a water-soluble blue pigment, called phycocyanin, plus one or more carotenoid pigments. The absorption curves for a typical set of these pigments is presented in Figure 12. It is interesting to note that the sum of the per cent absorption is about 100 over the entire visible spectrum. Chlorophyll itself absorbs light appreciable only in the red and violet regions. From the curves in Figure 12, it would appear that practically all incident visible light is absorbed by the pigments in blue-green algae. Whether light over the entire visible spectrum is used in photosynthesis is somewhat doubtful. The green color of leaves, green algae, etc., is due to the fact that light in the green region of the spectrum is not absorbed appreciably and hence is reflected preferentially.

The blue-green algae were selected as objects of experimentation because they are generally considered to have been derived directly from the earliest photosynthetic plants without appreciable change. A generalized distribution of plant group development during the geological periods is shown in Figure 13. Traces of algae are found in the Pre-Cambrian rock, the oldest rock found on the Earth's surface. However, bacterial traces are also

FIGURE 12-
ABSORPTION SPECTRA OF PIGMENTS IN BLUE-GREEN ALGAE



found in rock of the same age, so geological evidence is not sufficient to settle the point as to whether the photosynthetic plants preceded the hetrotrophic plants in the evolutionary sequence or vice versa.

We are culturing several species of blue-green algae, both fresh-water and marine, in an effort to determine (a) the elements essential to this growth, and (b) the functions of the elements. Neither investigation is particularly easy to do, al-

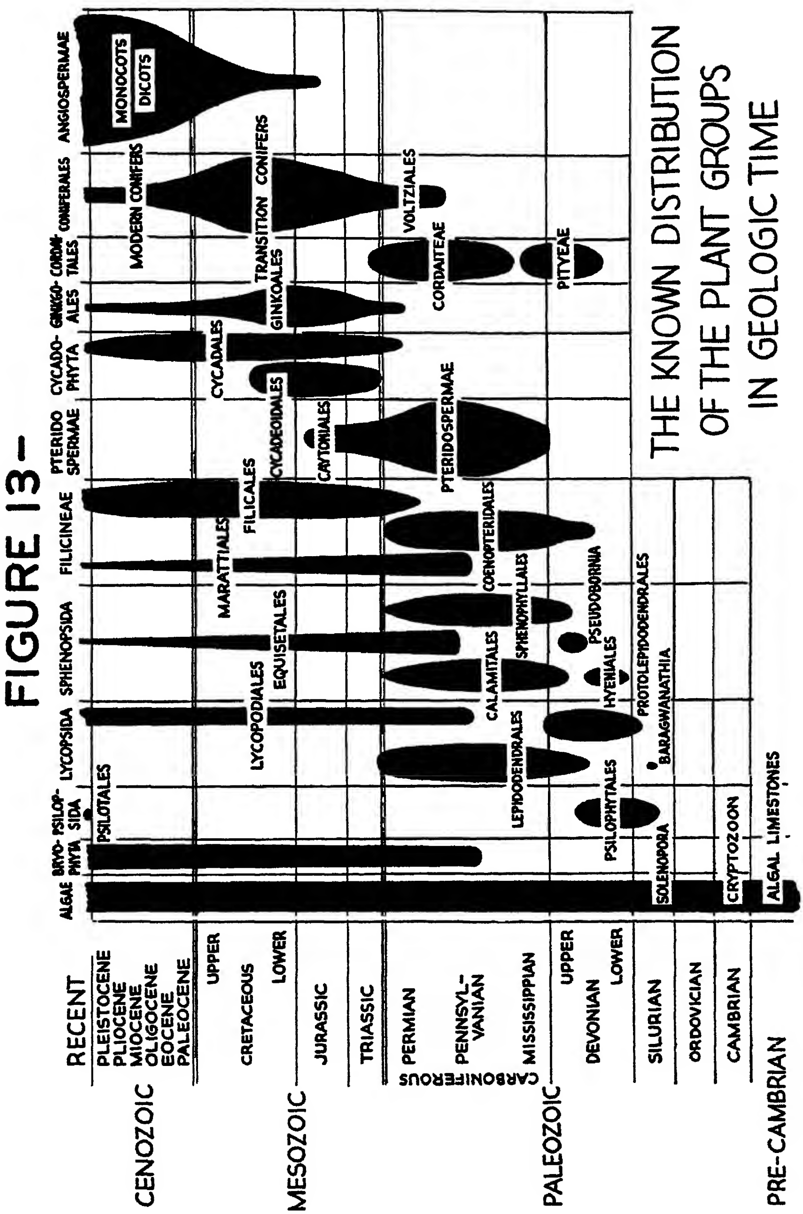


FIGURE 13—THE KNOWN DISTRIBUTION OF THE PLANT GROUPS IN GEOLOGIC TIME

though modern techniques in analyzing for and removing trace elements are very helpful. The determination of the function of the various elements will be comparatively difficult to achieve and complete success within a short period is doubtful.

It is believed that one or more of the elements in the algae

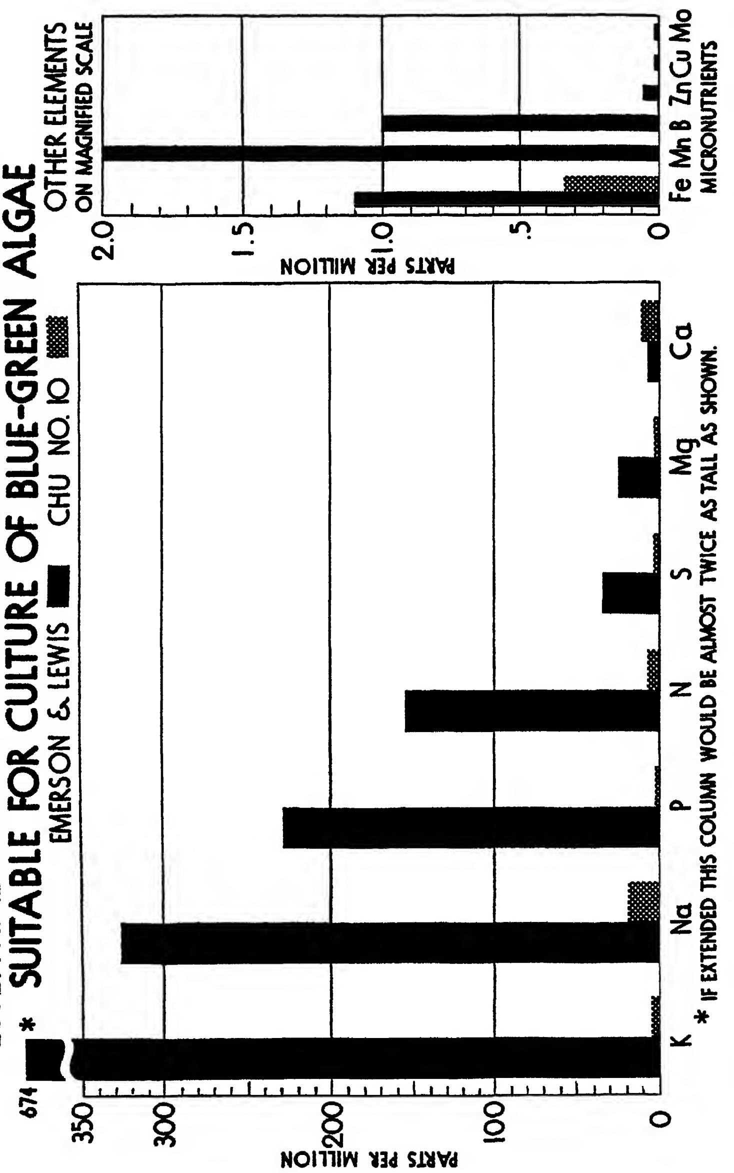


FIGURE 14— ESSENTIAL ELEMENT CONTENT OF NUTRIENT SOLUTIONS SUITABLE FOR CULTURE OF BLUE-GREEN ALGAE

nutrient solutions are active in the photosynthesis process, and our algae researches are aimed at determining just which element or elements is involved. The program consists initially of growing algae in flasks of inorganic salt nutrient solutions deficient in various elements. The composition of the two most commonly used nutrient solutions for blue-green algae are shown

in Figure 14. Note that there is very little similarity either in total amounts of each element or in their ratios. Both nutrient solutions have a pH which is slightly on the alkaline side as the blue-green algae do not grow well in acid solution. We believe that the pH is of primary importance and that as long as all the elements necessary are present, the concentration of each is relatively unimportant as long as toxic amounts are not reached.

However, the list of elements generally considered essential to the higher green plants, is not complete, at least not for the blue-green algae. We have shown this to be true by making up nutrient solutions with only the known essential elements added. By repeated series of subculturing we have found that the amount of total growth of algae in each new subculture tends to grow less for a while and then reaches a relatively weak steady amount. We interpret this as meaning that impurities furnish a certain amount of all the essential elements but if every essential element were added in reasonable quantity the growth would have been heavy. When nutrient solutions are inoculated from a few cells from an agar slant the growth is always heavy, probably due to the large amount of the trace elements picked up and stored by the cells when growing off the agar slant. Agar contains a large number of elements as impurities, and these no doubt become available to the cells as they grow in contact with the agar.

Some recent work in the Chemistry Department of the Ohio State University under the Kettering Foundation sponsorship has given some evidence that hydrogen peroxide may be the important reducing agent formed by the photodecomposition of water and hence the intermediate capable of reducing carbon dioxide in the plant. Hydrogen peroxide usually acts as a rather powerful oxidizing agent, but in certain cases it can be a reducing agent. This property is due to the tendency for the extra oxygen atom in hydrogen peroxide to unite with an oxygen atom in the other compounds to form O_2 gas. The net effort is the reduction of the other compound.

We are placing the emphasis of our research program at present on the following:

(a) The formation of H_2O_2 from water by light in the presence of ZnO or other catalysts.

(b) The photochemical decomposition of water by light in the presence of inorganic cations such as ferric-ferrous.

(c) The physics of the interaction between radiation and matter.

The above description of the photosynthesis research program of the Charles F. Kettering Foundation is of necessity quite condensed and simplified. However, the basic "prebiological" approach was explained in some detail, and it is this approach that we are hoping will yield practical results within the next few years.

A. L. LANG

Prof. Lang was born September 7, 1896, at Dilsboro, Indiana. He graduated from the University of Illinois in 1920 and from Cornell University in 1929. Since his graduation from Illinois he has given practically all of his time to an intensive study of Illinois soil fertility problems with the exception of that spent in graduate work at Cornell. This largely has been concerned with the great number of investigational centers systematically arranged over the State of which he is now in charge. These include the classical fertility plot studies located at Urbana which are now among the oldest continuing investigations of this nature in existance.

I. SOURCES AND RATES OF PHOSPHORUS APPLICATIONS

THE USE OF ROCK PHOSPHATE IN ILLINOIS DURING AND SINCE THE TIME OF HOPKINS

A. L. LANG

INTRODUCTION

In order to do justice to my subject I shall review briefly the early literature related to soils work of the Illinois Experiment Station. This review is not intended to eulogize, but it is an attempt to put in writing what I believe are important facts and as I think they ought to be recorded.

Only those who studied under Hopkins or who have taken time to read his literature intimately can have any conception of his thinking. It seems fitting, therefore, after 50 years that his guiding principles, formulated at the very beginning of his work, be reviewed and again recorded. The sincere belief of Hopkins in the absolute necessity for preservation of soil productivity and a demand from his superiors for a permanent system of agriculture led to his conception of the Illinois System of Permanent Soil Fertility. Into this system he incorporated the use of crushed limestone from vast local deposits, finely ground unacidulated rock phosphate direct from mine to farm, farm-produced residues as a source of organic matter and potash and free legume nitrogen from the air.

A short discussion of the system will be given to make the fundamental principles involved more clearly understood. Then information which has a bearing on the use of rock phosphate in the system will be presented.

EARLY HISTORY

Up to 1900 Illinois lagged far behind her sister states in making facilities available for teaching and investigating agricultural subjects. The first soil experiment plots established were not designed to study soil improvement, but rather to demonstrate soil depletion. I refer to the Morrow plots started in 1876. They are still being maintained and are serving their purpose well. Not until 1904 were portions of these plots utilized for soil improvement practices.

Beginning in 1879 with enactment of the Hatch Act, carefully conducted experiments with fertilizing materials applied directly for grain crops showed no appreciable benefits from such practices. Only good effects of animal manures and turned under clover meadows seemed worthy of note. I bring this in to point out that even before the turn of the century fertilizing

individual crops did not appear practical in Illinois. But a hazy conception of soil care as a function related to soil rather than crop culture was slowly developing.

During this early period, President Draper of the University probably pulled the prop that launched the boat when he pronounced the often quoted adage, "The wealth of Illinois is in her soils and her strength in their intelligent development." This statement was undoubtedly a challenge to Davenport, Director of the Experiment Station, and to Hopkins. It is still a challenge to all of us.

The members of the Illinois State Farmers' Institute, an organization which came into being by an act of the Illinois legislature in 1895, probably had more influence on early agricultural education and research programs of the state than any other person or body of people because from the time of inception its members took responsibility for sponsoring appropriations for such activities. Many members were the first to put into practice and demonstrate the practicability of findings and teachings from such research. Such men as Mann, Allen, Abbott, Wilson, Hinkley, Meis, and many others will long be remembered as contributors in this way. However, it is very evident that members of this organization were first inspired through efforts of Davenport, and then later by Hopkins and his co-workers. Addressing the second annual meeting of the Institute February 23, 1897, Davenport kindled members of that organization into action by revealing history of the scourge of soil depletion and its effect on past civilization. In that address he made these significant statements: "With all our boasted knowledge of agriculture, we cannot today with confidence lay down practices that will be safe and profitable and that will sustain productive capacity of these prairies for 1,000 years. I say without fear of contradiction, our race does not know how to do it." He further stated, "This is a problem whose solution we cannot too soon begin if we feel a racial pride and would do our duty to posterity."[1]

In the statements of Draper and Davenport we see need and administrative demand for a permanent system of soil preservation. In 1900, largely through efforts of the Farmers' Institute, the State Legislature appropriated money for the most commodious agricultural building then in existence, and the following year in 1901 under the same influence the legislature appropriated $10,000 for the purpose of soil investigations. Investigation started by that appropriation and continued by subsequent and larger ones have been largely responsible for continued widespread use of rock phosphate.

HOPKINS

Cyril G. Hopkins was made head of the Department of Agron-

1—Report, Illinois Farmers' Institute, Volume 2. 1896.

omy and given a first chair in Agronomy at the University of Illinois in 1900. He was an untiring worker with a keen mind and an art of sifting important from unimportant facts. In a short span of time he accumulated known facts of agriculture from all over the world and made widespread practical applications of his findings.

With the first appropriation from the legislature in 1901 made available for the specific purpose, Hopkins launched a state-wide program of soil investigations. Hopkins himself maintained until the last that Davenport was responsible for their inception.[2] Anyway, the scope, intensity, and continuity of these investigations have never been equalled before or since. There were 3 objectives set up.[3]

First, to determine the stock pile of total plant food in the most extensive soil areas of the state by collecting and analyzing soil samples.

Second, to determine the productive capacity of different soil treatments and different plant foods in terms of crop yields by means of controlled greenhouse pot culture and extensive field experiments.

Third, to locate boundaries of the most extensive soil areas and minute soil types in the state by first making a hurried general survey followed by a detailed survey down to each 10 acres.

With exception of the first part of this program the original plan is being continued almost in its entirety 50 years after its inauguration. Here it is worthy of note that Hopkins himself acquired most of the analogies of which he taught and wrote in respect to the fundamentals of permanent soil fertility from findings of chemical analysis in the early part of his investigations. Hopkins used experimental data furnished him by investigators in other states and countries to confirm his own convictions before his own data were available for that purpose. From his early publications it is evident that Hopkins had a clearly defined system of permanent soil fertility in his mind at the beginning of his investigations. At the annual meeting of the Illinois Farmers' Institute in 1903 Hopkins stated, "There is but one answer to the question of maintaining the fertility of all the soils which have been ruined in the past ages. This is the answer. Preserve good physical condition, put back on the land all the fertility which is taken off, not some of it, not most of it, but all of it and not only that which is removed by cropping, but also that removed by blowing, washing or leaching of the soil."[4]

Along with this pronouncement he offered five rules for improving soils and feeding plants. They are:

2—Illinois circular 157, March 1912, page 14.
3—Illinois circular 64, 1903.
4—Illinois circular 68, pages 2 and 3, April 1903.

1. If soil is acid, apply lime.
2. If soil is poor in nitrogen, grow clover.
3. If soil is poor in phosphorus, apply bone meal or some other source.
4. If soil is poor in potassium, apply potassium chloride or some other material containing potassium.
5. Always save all animal manures and make liberal use of green manures.

Following this, Hopkins stated that only three forms of phosphate should be considered for use in Illinois. These are:

1. Finely ground bone.
2. Finely ground rock phosphate.
3. Finely ground basic slag.

This may have been his first public announcement on rock phosphate. In supporting this statement he reports significant data from both Ohio and Maryland having to do with the carriers of phosphate and makes this statement, "All of these experiments strongly indicate that finely ground rock phosphate as well as bone meal will be a valuable form of phosphorus to use in Illinois." This is interesting in light of the fact that only one year before 15 soil experiment fields has been established on which bone meal was used exclusively as a source of phosphorus. There is no doubt that during the early part of his career Hopkins garnered most of his facts from statements by workers of other states. He acknowledges this later in his writings and takes no credit for establishing the fact that rock phosphate was a good source of phosphorus for direct application.

One example will serve to illustrate this point. Director Thorne of the Ohio Agricultural Experiment Station spoke on the same Illinois Farmers' Institute program with Hopkins in 1903. At this meeting in commenting on the increase of wheat yields in Ohio over a 50-year period, he said, "It has nevertheless been accomplished at so large an expenditure for commercial fertilizers as to leave it open to question whether there has been an actual gain. The result is that our fertilizer costs have run up to an average of more than a million and a half dollars annually, about one-third of which we pay for being persuaded to buy. Let me not be understood as condemning the use of fertilizers. On the contrary, I regard the utilization of the great deposits of phosphate rock, nitrate of soda, potash salts, and the waste from our slaughter houses as one of the greatest steps in modern agricultural progress. When blind, haphazard use of these materials takes the place of an intelligent study of the fundamental principles of agriculture as it too often has been done in Ohio, they become a curse instead of a blessing." Later in the same paper, Director Thorne states that a ton of stall manure was increased in value from $2.50 to $3.25 when 40 pounds of phosphate rock was added to each ton for the purpose of re-inforcing the

manure with phosphoric acid and preventing the escape of ammonia.[5]

Many remember Hopkins only as the great proponent of rock phosphate. This is unfortunate because it does an injustice to his teachings to present science and the rock phosphate industry. The facts reveal that Hopkins 50 years ago was more nearly aware of the great need for nitrogen and potassium fertilization than many present day agronomists. His great quarrel with the fertilizer industry had to do with the lack of proper nutritional balance and costs that made adequate application unattainable.

To meet adequately the demands of crops for nitrogen Hopkins recommended and used in his early experiments 100 pounds of nitrogen annually. This makes pikers out of most of us. His work demonstrated the crying need of crops for nitrogen and pointed to the great deficiencies in the seemingly fertile Illinois prairie soils. Furthermore, the work demonstrated the utter impossibility of ever supplying this enormous need through commercial channels. Widely distributed experiments over the entire country are still demonstrating these glaring facts. At present, favorable price ratio between nitrogen fertilizers and farm crops offer a great opportunity for using large quantities of commercial nitrogen. (Unfortunately supplies are relatively scarce.) Even as most agronomists today are doing, Hopkins concluded that legumes would have to be relied upon as the major source of this important nutrient. Hence the soil management problem resolved itself into one of growing legumes. Legumes to be grown in Illinois required large quantities of limestone and much more phosphorus than the soils could supply. Since phosphorus in the available sources of mixed fertilizers was far too costly to encourage adequate applications for maximum legume production, and since legumes had demonstrated their ability to utilize phosphorus from rock phosphate, Hopkins saw in this source a means of getting the job done. This logic is still good.

The Illinois System of Permanent Soil Fertility

Out of all this came the Illinois System of Permanent Soil Fertility in which rock phosphate has a part. It is a plan of soil management recommended for building up and maintaining permanent productivity. The objectives of the plan are to keep soil physically fit, chemically balanced, and biologically active. Fundamental to the plan are recommendations by which the objectives are accomplished. Herein controversies arise as would be expected when dealing with the many ramifications brought about by forces of man and nature on a dynamic, biologically active medium such as the soil. Principles underlying recommendations in the system result from an economic analogy relating long-time average agricultural incomes in the Corn Belt to

5—Illinois Farmers' Institute report, 1903.

possibilities of getting the job done. This analogy was based on existing facts which are as true today as when they first were pointed out. These were:

1. Cultural practices used in general agriculture were exploitive. "Tickle the earth with a hoe and she laughs with a bountiful harvest. When the tickling fails to produce, new fields to impoverish are sought, and westward the course of empire takes its way, with ruined lands behind." That was the song of the prairies.
2. Exploitation could not continue if civilization and a free people were to survive.
3. Incomes from general farming practices were relatively low. For example, from 1900 to 1911 the average prices in the Corn Belt were 70 cents for wheat, 35 cents for corn, 25 cents for oats and $6.00 a ton for hay.
4. Commonly recommended fertilizer practices were too costly to encourage adequate applications. Phosphorus in the most common fertilizer, 2-8-2, costs 30 cents a pound. The potash in such a fertilizer would dilute an Illinois soil. Costly burnt limestone was being recommended as a source of lime for correcting acidity and furnishing calcium.

To meet the challenge of soil exploitation in the midst of adversities of low income and costly replenishment, Hopkins reasoned that Illinois farmers could use larger quantities of less expensive crushed limestone from vast local deposits, legume nitrogen free from the air, inexpensive untreated rock phosphate and could make judicious use of all farm-produced residues for organic matter and for liberating a much needed and abundant supply of potassium from the soil.

In that reasoning is embodied the basic principle underlying the Illinois System of Permanent Soil Fertility. Furthermore, those are the principles which from the beginning have kept our research work and our extension teachings on a straight, definite, systematic, simple, easily understood, easily applied, and workable soil improvement program. There have been no byways, and no tangents, no delays, but a constant forward effort to improve on, add to and compare.

Why Rock Phosphate?

From his own analogies Hopkins reasoned that phosphorus was the key to permanent agriculture. With $1,000,000 worth of nitrogen over every acre of the land and available to the soil through legumes, he argued that Illinois farmers need not buy a pound of that most important nutrient. Likewise, with enough potash in each acre of land to last for 19 centuries he maintained that some system should be used to make it available, thereby avoiding purchase from outside sources. Phosphorus, however, was different. Surface soils showed only enough total phosphorus

to last one man's lifetime. Hence, if permanent fertility was to be maintained this essential nutrient would have to be purchased and returned to the land from outside sources. Also it would have to be returned in proportion to that taken from the land through cropping, wind erosion, leaching, and washing. Bone meal, basic slag, rock phosphate, and superphosphates were on the market in the early days as they are today. Hopkins contended that bone meal was the ideal source of phosphorus for Illinois farm land, because it was a farm product, and its return to the soil tended toward a permanent cycle. He pointed out, however, that its cost discouraged the use of maintenance quantities. Likewise, price was unfavorable to basic slag and acid phosphates, therefore, rock phosphate costing only $7 to $8 a ton delivered to Illinois farms offered the more ideal source of phosphorus for this purpose.

Thus Hopkins set out to learn about rock phosphate, and he gathered together in detail all of the available experimental evidence on the subject of phosphatic fertilizers. His interpretations of the many long-time experiments which preceeded by far his own research work are available in the many early circulars of the Illinois Station.[6] Briefly it was the long-time experiments from Maine, Massachusetts, Maryland, and Ohio that in the mind of Hopkins established beyond a doubt that rock phosphate was the most economical source of phosphorus for use in permanent systems of soil fertility maintenance.

From this acknowledgment Illinois cannot claim credit for first establishing the fact that rock phosphate was an economical source of phosphorus for permanent systems of agriculture. Many times in his early teachings, Hopkins pointed out that the famous old manure experiments at Ohio comparing rock and acid phosphate were the World's greatest contribution to Illinois farms. In the beginning of those experiments, both Director Thorne of the Ohio Station and Hopkins interpreted them as favoring rock phosphate. Later, however, their interpretations became a controversial matter and Hopkins stayed on the rock phosphate side.

Hopkins maintained there was little use of further study on the matter of phosphate carriers. For Illinois the problem was settled. Consequently, since 1903 rock phosphate has been the main source of phosphorus for farm use and for all major experiments in the state.

According to Hopkins the first carloads of rock phosphate purchased in the state were probably used for experimental work. However, the records show that in 1903, A. A. Hinkle of DuBois purchased 1½ cars of rock phosphate. This may be the first record of its farm use in Illinois. His results and those of the experiment fields were so encouraging that its use spread rapidly

6—Illinois circulars 86, 96, and 97 and Illinois bulletin 99 are most important.

Tab

Current Farm Prices
Increases for Soil Treatment Practices

		Check	M	L/M	P/ML	MLP	L/O	P/L	K/LP	LPK*
I	Aledo	$63.20	$22.26	$ 3.73	$-1.29	$24.70	$11.71	$ 2.36	$ .58	$14.65
II	Hartsburg	76.43	28.23	2.07	.38	30.68	7.16	2.48	- .03	9.61
	Minonk	71.49	14.63	- .72	-3.04	10.87	1.34	4.14	.23	5.71
III	Kewanee	52.72	19.55	4.36	- .86	23.05	11.25	2.32	-3.99	9.58
IV	Dixon	57.96	25.74	7.43	.78	33.95	12.58	6.20	4.38	23.16
	Mt. Morris	41.86	26.46	8.09	- .32	34.23	27.77	3.60	-3.10	28.27
V	Carlinville	50.74	26.72	19.26	7.27	53.25	19.28	9.87	9.69	38.84
	Carthage	58.95	21.59	8.03	1.63	31.25	11.66	.19	2.45	14.30
	Clayton	54.43	21.29	6.85	1.90	30.04	10.56	4.80	- .36	15.00
	Lebanon	54.09	42.06	14.14	-1.67	54.53	29.82	1.54	10.38	41.74
VI	Joliet	49.39	17.22	2.06	10.33	29.61	3.11	14.90	3.87	21.88
VII	Ewing	20.42	15.21	29.01	6.25	50.47	10.18	6.82	30.54	47.54
	Newton	15.35	17.03	34.22	4.51	55.76	21.89	5.14	10.36	37.39
	Oblong	29.43	20.23	26.57	3.53	50.33	16.00	5.69	20.75	42.44
	Toledo	23.19	24.11	19.80	- .57	43.34	15.53	.63	29.14	45.30
X	Enfield	15.75	17.39	25.20	6.24	48.83	16.17	6.71	9.43	32.31
	Raleigh	15.55	10.75	23.64	.77	35.16	11.85	6.32	11.77	29.94
	Sparta	7.47	9.39	35.00	2.17	46.56	27.40	1 16	17.67	46.23
XIV	Oquawka	18.07	9.62	19.14	- .19	28.57	16.50	.23	10.19	26.92
XVI	Elizabethtown	9.98	19.77	21.05	8.19	49.01	18.42	12.64	8.58	39.64
	Average	$39.32	$20.46	$15.45	$ 2.30	$38.21	$15.01	$ 4.89	$ 8.63	$28.52
									cost	5.25
									diff.	$23.27

M - manure - equal in weight to crops removed
L - limestone - equivalent to approximately 500 pounds annually
P - rock phosphate - equivalent to approximately 200 pounds annually
K - potassium chloride - equivalent to 100 pounds annually
Values - Current prices received each year at the farm.
*Does not include value of residues returned without treatment. This would average 8 to 10 dollars annually.

throughout the state and has continued from that time on. It is estimated that approximately 27,000 tons were used from 1903 to 1920, during which time there is no official record. Since 1920 Illinois has used 3,670,422 tons. The trend has been constantly upward. The peak of use was reached in 1947 when more than 600,000 tons were applied to Illinois farm lands. That figure along with P_2O_5 supplied in mixed fertilizers and superphosphate enabled us to say that Illinois was applying more phosphorus than any other state in the United States. This could not have been accomplished during or following a wartime emergency without our rock phosphate program.

A Few Farmer Experiences

From the very beginning, farmers themselves were the most enthusiastic supporters and promoters of the system. There are the printed statements of such men as Brother Leo, long-time manager of the Notre Dame 1,000-acre farm at South Bend, Indiana,[7] Frank I. Man, Gilman, Illinois,[8] records of Hopkins' own "poorland farm," Salem, Illinois,[9] Allen Meis, Hinkley, and many others.

Records of the Farm Bureau-Farm Management Service are the best source of information on present day accomplishments. The Farm Bureau-Farm Management Service is a cooperative management service between farmers and the Agricultural Economics extension staff. The field technicians paid by the farmers aid in the keeping of exacting records of the farms' enterprises. Professor M. L. Mosier of the Agricultural Economics staff at the University of Illinois in summarizing long-time records from these farms revealed that farmers putting into practice recommendations of the experiment station have equalled or bettered results of field research findings. The records proved beyond any doubt that some Illinois farms can average and have averaged more than 100 bushels of corn an acre on their entire farm in good years and over a period of years.[10]

Results From Field Experiments Show How Farmers Benefit

A summary of the yield on the bases of current farm prices for long-time or rotation periods brings out noteworthy information. The following data from Table 1 is an analysis of figures from the last rotation period on 20 outlying soil experiment fields.

These show that organic matter either as animal manure or crop residues has been the most important factor in increased

7—Illinois circular 186.
8—Illinois Farmers' Institute Report, 1911, page 95.
9—Illinois circular 168,
10—Illinois News Release, 1950.

crop production. Values given to other soil amendments largely measure their ability to produce organic matter which can be returned to the soil.

Interpreted this way, limestone has returned more per dollar invested than any other soil amendment. Largely because of these facts Illinois farmers have been induced to use about one sixth of all the lime used in the United States and have profited handsomely by it. We think it is very fortunate in Illinois that the lime program has not been overshadowed by more glamorous but less profitable practices.

Rock phosphate on the ten fields where phosphorus has been profitable to use in addition to limestone and manure has returned $4.00 per dollar invested.

Rock phosphate and potash in combination over lime on 12 fields where both are needed has returned more than $5.00 per dollar invested in the two.

As an average on all fields limestone and rock phosphate have returned annually $17.75 an acre over manure. In grain systems, limestone, rock phosphate and potash have returned $28.52 an acre annually.

The annual acre cost of the limestone, rock phosphate and potash in the grain system of farming has been $4.50 and the annual return per dollar invested has been more than $6.00.

These are the kinds of facts and figures that keep up our enthusiasm.

Progress

Some will ask, "How much progress has been made since the time of Hopkins?" The answer is much. It can be substantiated. But if none had been made I feel I am safe in saying for the field research staff that we are proud of the fact that we have carried on. To hold the line against the pressure of opposition with glamorous proposals has not been easy for a young college staff who are ambitious and trying to make reputations. You can recall that it was a completely new and young staff that took over the agronomic work at Illinois when Doctor Hopkins was called from it.

For the continuity of the work, Dr. W. L. Burlison, who carried the responsibility as head of the department, deserves more credit than history will record. Even though from the beginning of his administration pressure has been constantly on him to discontinue much of the work started by Hopkins, he has held steadfast. Convinced that it was right, he has been willing to see the work of his predecessor carried on successfully rather than to launch out on a new program of his own.

Illinois is perhaps as fortunate to have had a Burlison as it was to have had a Hopkins. But for Burlison the entire efforts of Davenport, the Illinois State Farmers' Institute, and Hopkins

might have been pushed aside and lost. We could have and still can degenerate into a blind haphazard unscientific use of plant food materials as condemned by Thorne 40 years ago. May we be blessed with leadership during the next 50 years as strong as that which we have had during the past.

EXPERIMENTAL EVIDENCE

From the very beginning the benefits to be derived from the use of rock phosphate in Illinois have been supported by experimental field data.

The Muscoutah Field in St. Clair County which was operated from 1904 to 1913 furnishes data given in Table 2 which is typi-

TABLE 2.—MUSCOUTAH FIELD
1904 to 1913

Crop	Corn	Oats	Wheat
No. of Crops	8	4	4
	bu.	bu.	bu.
Check	39	33	23
Acid Phosphate	42	40	25
Rock Phosphate	46	38	26

Initial application 400 pounds of acid phosphate. 1,000 pounds of rock phosphate with continued 200 pounds of acid and 500 pounds of rock each rotation.

TABLE 3.—LIMESTONE, ROCK PHOSPHATE, SUPERPHOSPHATE COMPARISONS ON 14 OUTLYING ILLINOIS SOIL EXPERIMENT FIELDS.

Average annual values of all crops on the rotation figures at current farm prices.

		ML	MLrP	MLsP	LeL	LeLrP	LeLsP
Aledo	27	54.02	54.41	54.47	45.80	46.91	45.87
Antioch	26					25.43	25.95
Bloomington	26					41.43	40.82
Brownstown	11					32.27	35.27
Carthage	22	44.15	44.40	44.74	38.16	40.34	40.10
Dixon	27	44.93	45.28	45.65	37.27	39.80	39.67
Ewing	22	34.61	36.80	35.80	24.68	33.15	31.06
Hartsburg	27	49.33	50.63	50.04	41.74	44.88	45.35
Lebanon	22	50.47	50.74	49.15	43.37	43.88	42.58
Minonk	11	67.80	66.80	68.50	56.32	59.87	59.86
Oblong	12	53.43	56.09	56.93	45.88	50.10	47.19
Raleigh	27	23.74	26.65	26.33	15.74	20.44	20.45
Sparta	21					27.10	26.95
Toledo	21		37.86	39.38		34.72	34.32
Average			45.34	45.33		37.54	37.17

Lime is applied to give a range of pH 6 to 6.5.
Phosphates on most fields have been applied at approximately equal money values.

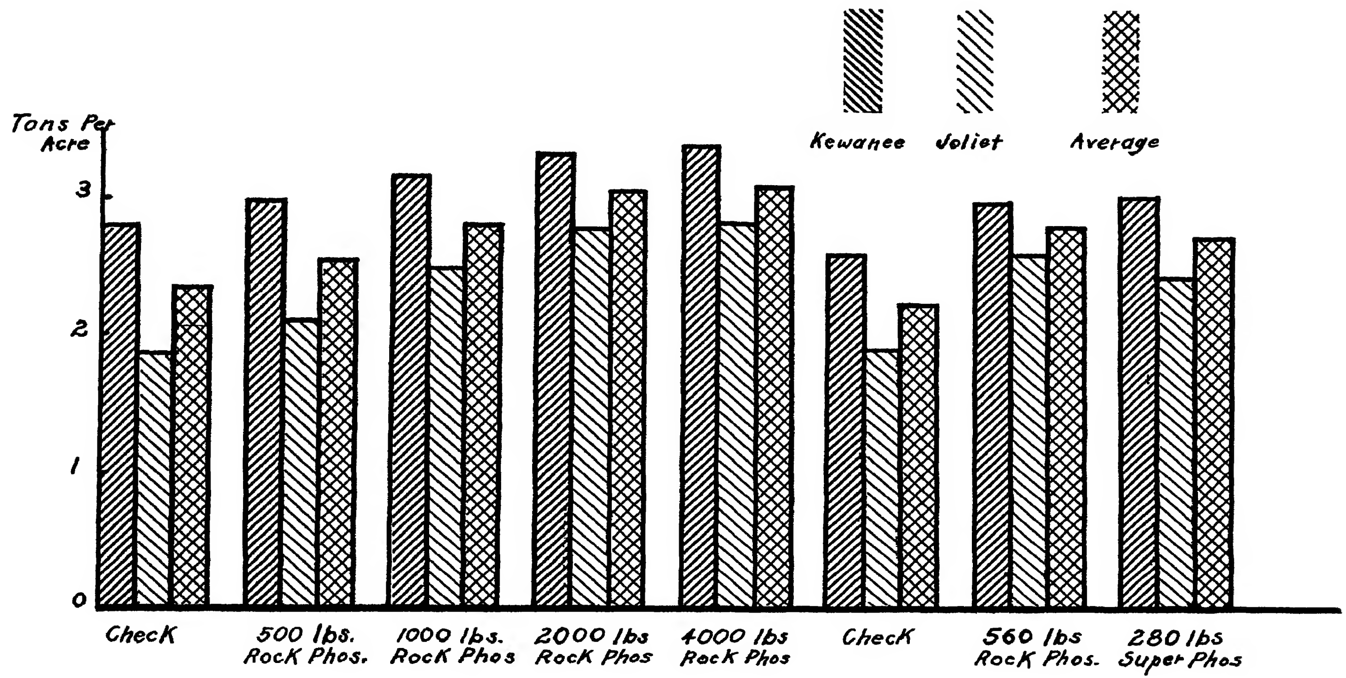


Figure 1—EFFECT of PHOSPHATE FERTILIZER on LEGUME HAY YIELDS

cal of some of the early comparisons on phosphate carriers. Like that of other fields the data from Muscoutah show that rock phosphate is an effective source of phosphorus when compared to superphosphate.

Since 1924 the present experimental field staff has been trying to accumulate more and more evidence on the relative merits of rock and superphosphate. At present almost every experimental field has work going on which contributes information on the subject. All of these data, however, have not lessened the enthusiasm for rock phosphate.

It has been found generally that when rock phosphate is not effective superphosphate is likewise ineffective. The exception to this is in high lime soils above pH 7.

Fourteen fields give an opportunity to compare rock and super over a long period of years when used in most cases at approximately equal money values. A summary is given in Table 3.

Some interesting data on rates of application of rock phosphate and comparisons with rock and super have been secured at Joliet and Kewanee. These data are shown in Fig. 1. From this work it appears that the law of diminishing returns on initial applications is somewhere between 1,000 and 2,000 pounds of rock phosphate an acre. This varies with soil type and phosphorus deficiencies. There was about equal response to each of the carriers when used with the legumes at equal money value.

At Urbana rock and superphosphate were compared at equal money values when top-dressed on permanent pasture sods at relatively small amounts annually over a period of 10 years. The results for the first 3 years are shown in Fig. 2 and for the entire period in Fig. 3.

The comparative value of rock and superphosphate was measured by Professor L. B. Miller of the field staff in semi-permanent cooperative experiments with farmers over a period of 12 years. The carriers were applied at equal money value and their values measured in corn yields. An analysis of the data given in Fig. 4 shows several possible advantages in the use of rock.

1. More phosphorus was applied to the soil.
2. More was removed by the crop.
3. More was left for future use.
4. The yield of corn was higher.

Of special interest is a unique study on the M-7 plots of the Agronomy south farm at Urbana. Here 1,500 pounds of rock phosphate were applied in 1935 and allowed to be residual for 15 years. At the same time in 1935 applications of superphosphate were begun at the rate of 100 pounds an acre a year. The super was continued until the same amount of money had been spent as for rock. This occurred in 1942, 8 years later, and then the super was allowed to be residual until the end of the 15-year

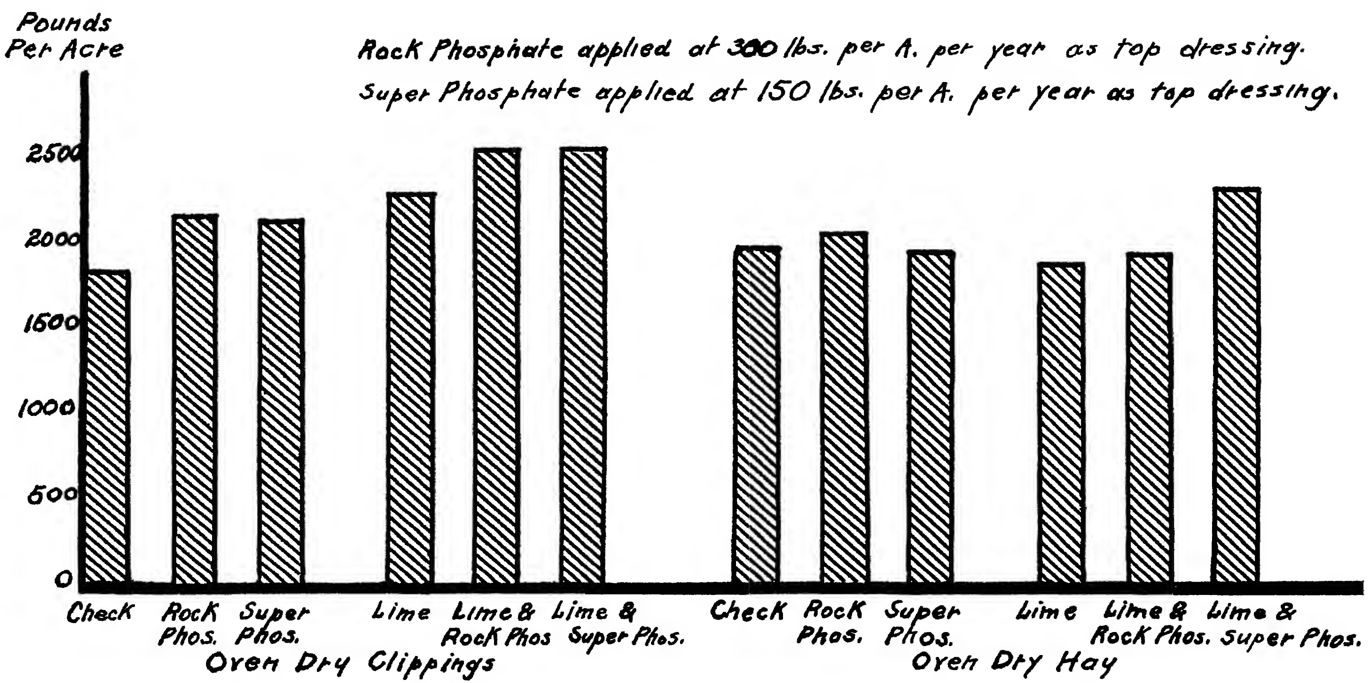


Figure 2.– M-14 Urbana First 3 Year Average Rock Phosphate vs. Super Phosphate on Pasture Grasses and Legumes

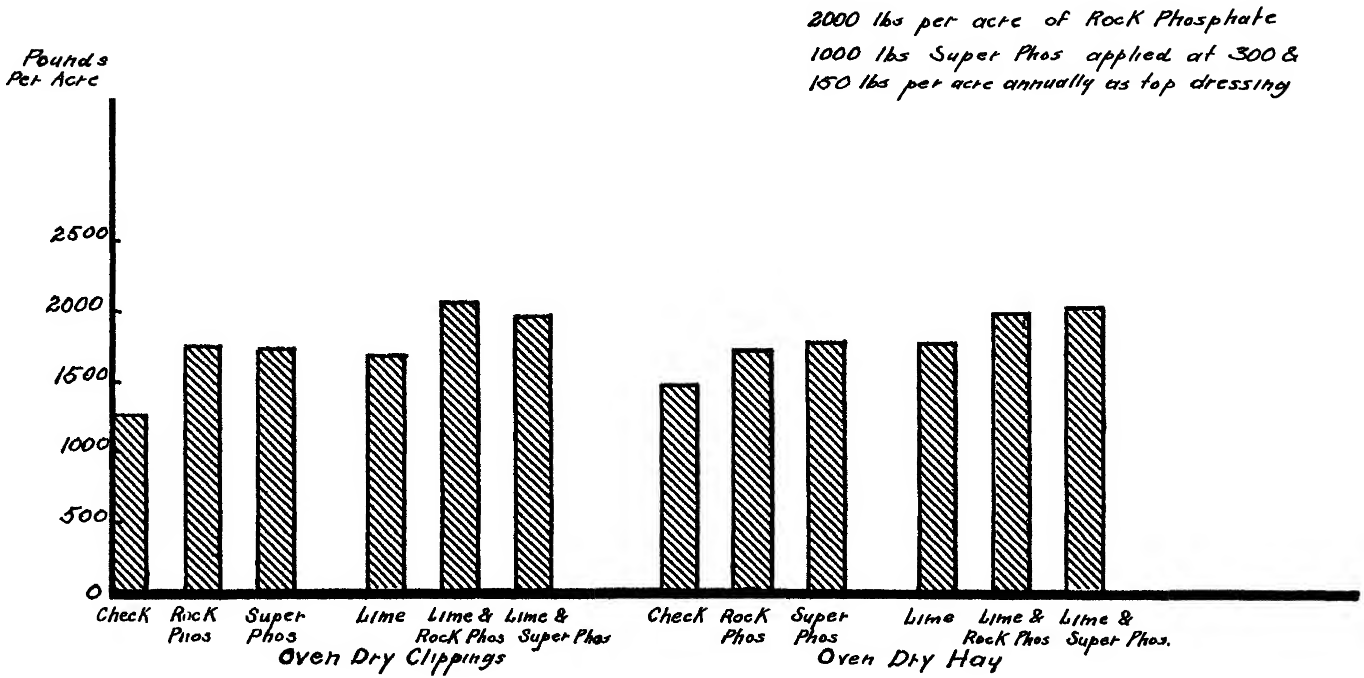


Figure 3.— M-14 Urbana 10 Year Average Rock Phosphate vs. Super Phosphate on Pasture Grasses & Legumes

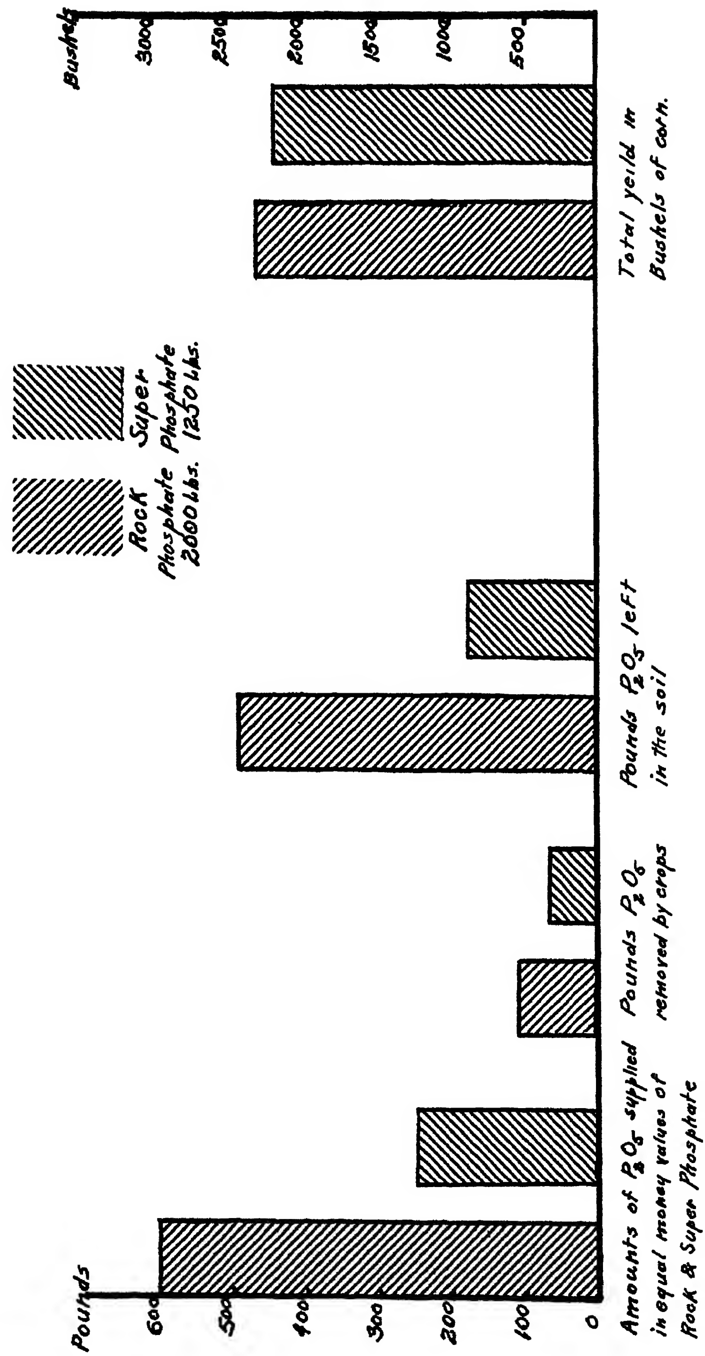


Figure 4-Phosphate Comparisons as Measured By 42 Corn Crops On 12 Selected Soil Types over a Period of 12 Years

period. Fig. 5 is a graph of the result trends. Rock phosphate returned a gross of $129.67 or $8.65 per dollar invested. Superphosphate grossed $73.54 or $4.90 per dollar invested. As this experiment progressed the crop showed need for potash. A new treatment was started in 1941 where 1,500 pounds of rock were applied in addition to potash. Fig. 6 shows the trend of the response to this treatment. In 9 years there was a gross return of $83.17 or more than from a similarly treated plot with superphosphate over a period of 15 years.

Recent Developments

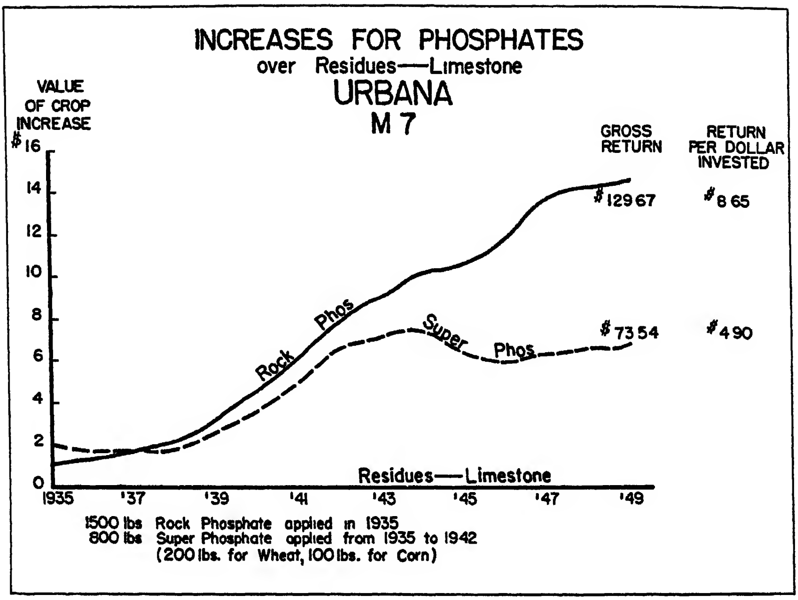
In recent years bulk storage and custom spreading have expanded so rapidly that one community may have four or five of these services. Rock phosphate lends itself especially well to this method of handling. In bulk storage of rock phosphate there is no corrosion, moisture absorption, or caking problems. The material remains in perfect condition until used. Custom spreading appeals to the user for several reasons. He saves the costs of bags and bagging, also labor and machinery for spreading. All this has made it easy to use. The yearly tonnage used figures shown in Fig. 7 for the last decade are ample proof.

The most recent development is custom blending rock phosphate with whatever amounts of nitrogen, potash, or both, may be needed on a field as determined by soil tests and management history. This service is being offered by several progressive distributors at the present time. This type of service is spreading very rapidly. It has a great deal of merit and may easily enough revolutionize the program of the entire fertilizer industry. The companies give a soil testing service then supply either a basic or maintenance application of rock phosphate blended with the proper amount of N and K. To me this looks like the first attempt by industry to actually try to apply plant food to the soil according to the deficiencies in the soil and the needs of the crops. It has all the advantages of a materials program and a package program without the disadvantages of either.

Custom blending works this way. For example, a field not previously treated shows by tests need for 80 pounds of N, 1,500 pounds of rock phosphate, and 200 pounds of KCl an acre. Such an order comes into the plant and the materials are weighed out in correct proportion from separate bins moving into the spreading truck as a unit, taken to the field and all applied in one operation. In case of maintenance requirements the rock phosphate may be cut to 400 or 500 pounds.

Summary

History, records, and new developments have been given relative to the use of rock phosphate in Illinois. They justify our continuous effort and enthusiasm for its use.



Figuie 5.

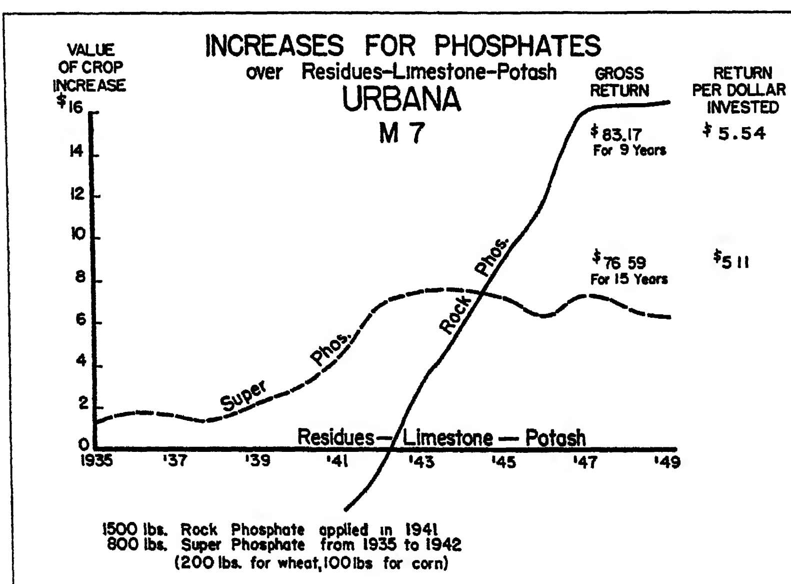


Figure 6.

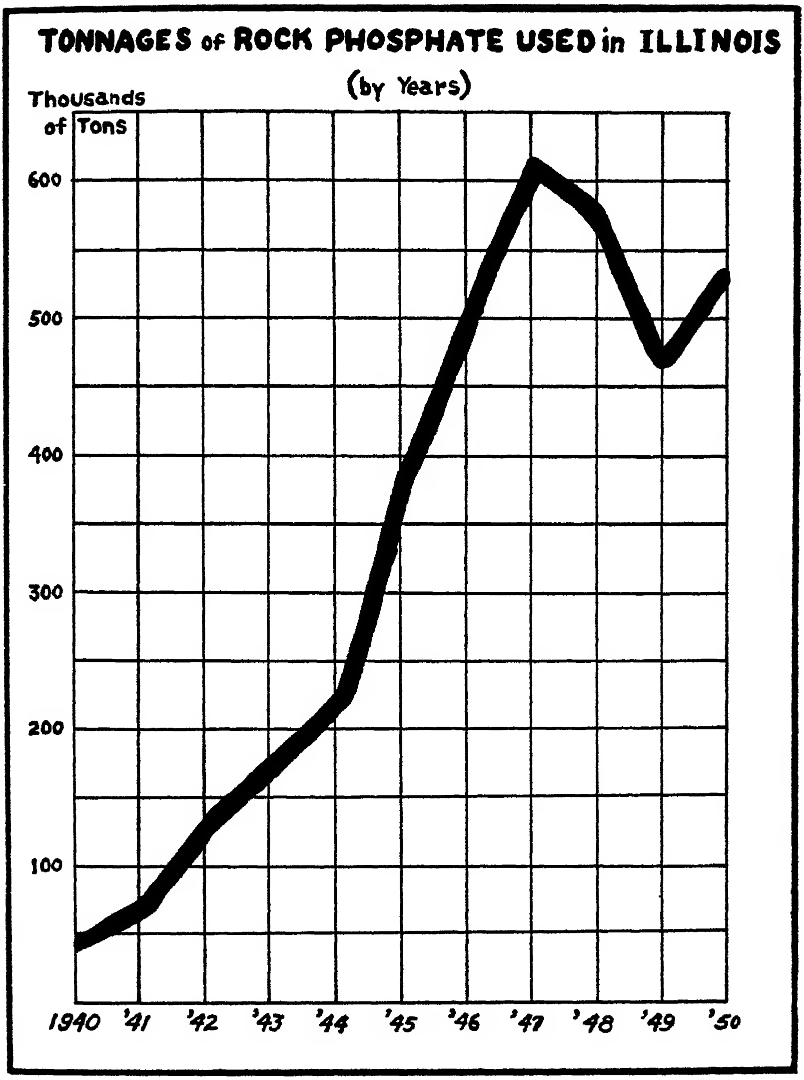

TONNAGES of ROCK PHOSPHATE USED in ILLINOIS
(by Years)
Thousands of Tons
600
500
400
300
200
100
1940
'41
'42
'43
'44
'45
'46
'47
'48
'49
'50

Figure 7.

Rock and superphosphate on unlimed soil, Raleigh soil experiment field, 1951.

Corn Yields Oblong Soil Experiment field, 1945.

(KN) Potassium, nitrogen	43 bu.
(RKN) Crop residues legumes (KN)	56 bu.
(RLKN) Limestone (RKN)	93 bu.
(RLPKN) Rock phosphate (RLKN)	104 bu.

Note: The Raleigh and Oblong fields represent some of the poorly drained level prairie soils with impervious sub soil layers of Southern Illinois.

M-11 plots Agronomy South Farm, Urbana, 1947.

(O) No phosphate	64 bu.
(RP) Rock phosphate	88 bu.
(O-20-O) Superphosphate	79 bu.

Note: All plots have limestone, potash and nitrogen applied. 1600 pounds of rock phosphate was applied in 1946. 100 pounds of O-20-O is applied annually to each crop in the rotation of corn and soybeans. The photograph is of the 1947 yields. The yield figures are a four year average including 1950.

Figure 8.

Dr. W. L. Burlison, Head of the Department of Agronomy, University of Illinois, explaining the basic work of the Morrow Plots to a group of visitors, always closes with the dictum "This work must go on."

UTILIZATION OF PHOSPHORUS FROM VARIOUS SOURCES

W. L. NELSON[1]

Superphosphate has been the standard source of phosphorus in commercial fertilizers with ordinary or single strength superphosphate being used much more than treble superphosphate in the Southeast. An important development in the commercial fertilizer field in recent years is ammoniation of superphosphate. This process favors the conversion of the monocalcium phosphate to the dicalcium and tricalcium forms. Rock phosphate and basic slag have been used for many years in certain areas. Lately, interest in other sources of phosphorus such as dicalcium phosphate, tricalcium or fused phosphate and calcium metaphosphates has increased.

The objective of this paper is to present information on source of phosphorus from the standpoint of efficiency of uptake of phosphorus by plants. Radioactive phosphorus has proven to be a valuable aid in such studies and much of the data reviewed will be based on work in which radioactive phosphorus was used as a tracer. Through such studies the efficiency of the various sources of phosphorus can be determined even without yield responses.

The utilization of certain sources of phosphorus will be discussed by crops.

COTTON

On a soil containing 67 pounds of P_2O_5 (Truog) the percentage of phosphorus in the plant derived from dicalcium phosphate was distinctly lower than from the other sources (Figure 1) (4). On a soil containing 288 pounds of P_2O_5 dicalcium phosphate again gave the lowest proportion of fertilizer phosphorus in the plant (Figure 2). On this soil alpha tricalcium was not so effective as the other three sources. Calcium metaphosphate was somewhat more effective than any of the other sources, however. In these experiments the fertilizer was placed in bands three inches to each side of the seed and two inches below. There were no significant differences in the yields of cotton obtained from the various sources.

CORN

On a soil high in phosphorus, 319 pounds of P_2O_5 per acre, corn plants receiving phosphorus as superphosphate and as calcium metaphosphate were consistently higher in percentage of

[1]—Director, Soil Testing Division, State Department of Agriculture and Professor of Agronomy, North Carolina State College of Agriculture, Raleigh.

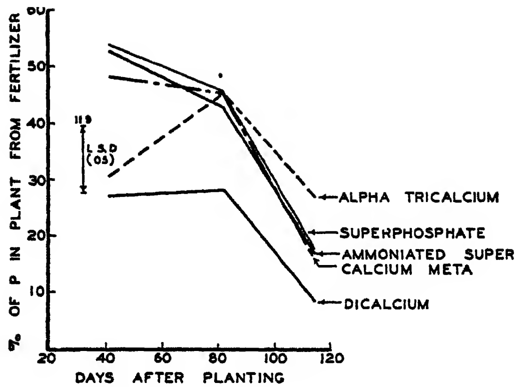


Figure 1.—Percentage of phosphorus in the plant derived from the fertilizer as influenced by the source of phosphorus for cotton on Norfolk sandy loam containing 67 pounds of P_2O per acre. (50 pounds of P_2O applied. The L.S.D. (.05) is for treatment means).

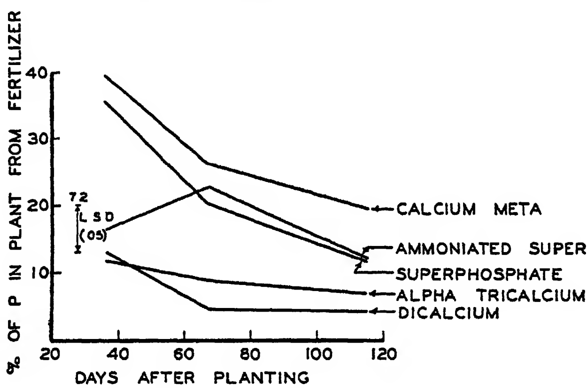


Figure 2.—Percentage of phosphorus in the plant derived from the fertilizer as influenced by the source of phosphorus for cotton on Norfolk sandy loam containing 288 pounds of P_2O_5 per acre. (50 pounds of P_2O_5 applied. The L.S.D. (.05) is for treatment means).

phosphorus derived from the fertilizer than those plants receiving alpha tricalcium phosphate (4). The percentage of phosphorus in the plant derived from each of the three fertilizer materials decreased consistently throughout the season. The fertilizer was placed in bands as described for cotton. There was no yield response to phosphorus on this soil.

SMALL GRAIN

In Iowa there was an interaction between the acidity of the soil and utilization of phophorus from the various sources (7). On a Clarion soil, pH 5.6, calcium metaphosphate was a less efficient source of phosphorus for oats than either dicalcium or

alpha tricalcium phosphate. However, on a Webster soil, pH 6.7, there was little difference among these sources. No source was better than superphosphate on either of these soils. The phosphorus was broadcast and disced in. There were no significant differences in yield.

In an experiment with wheat and barley in Colorado (6) superphosphate and calcium metaphosphate were much superior to dicalcium and tricalcium phosphates, with the two former sources giving increases in yield of wheat. This experiment was conducted on a calcareous soil.

TOBACCO

Work in North Carolina showed that ammoniated superphosphate, when compared with ordinary superphosphate, produced a slight decrease in percentage of phosphorus in the tobacco plant from the fertilizer (8). Ammoniation of superphosphate reduces the amount of water soluble phosphorus (5) as a result of the reversion of part of the monocalcium phosphate to the more insoluble dicalcium and tricalcium phosphates.

SUGAR BEETS

Experiments on calcareous soils in Colorado showed that superphosphate and calcium metaphosphate gave a higher percentage of phosphorus in the sugar beet plant from the fertilizer than did dicalcium and tricalcium phosphates (6). At one location the two former sources produced significantly higher yields than did the two latter sources.

There was an interaction between placement and utilization of phosphorus from the various sources (6). Placement of the phosphorus in a single band 4 inches deep and 4 inches to the side was compared with phosphorus mixed with a rototiller in a band 4 inches wide and 4 inches deep. There was a greater uptake of phosphorus from superphosphates and calcium metaphosphate when these sources were placed in bands. On the other hand, with dicalcium phosphate, the rototiller placement gave the greatest uptake of phosphorus. The availability of dicalcium phosphate is apparently influenced by the root-fertilizer contact. With the more soluble sources rather complete mixing with the soil may favor greater reversion than is obtained with band placement, however.

LEGUMES

Superphosphate gave a higher percentage of phosphorus in Ladino clover from the fertilizer than did calcium metaphosphate, tricalcium or dicalcium phosphates (1). This experiment was conducted on a Mardin soil, pH 5.3. As with sugar beets,

there was an interaction between placement and the utilization of the sources. There was a greater uptake of fertilizer phosphorus from superphosphate and calcium metaphosphate drilled than with these sources broadcast. Placement did not affect the uptake of phosphorus from dicalcium or tricalcium phosphates, however.

Fried and MacKenzie compared superphosphate and rock phosphate on soils having a pH of 4.9, 5.5, and 5.8 respectively (3). The rock phosphate was added in amounts to give approximately four times as much P_2O_5 as supplied by the superphosphate. Alfalfa and vetch were grown. The percentage of phosphorus in the plant coming from the rock phosphate decreased rather markedly with decreasing acidity. This reduction was not as noticeable with superphosphate. On the most acid soil alfalfa absorbed a considerably higher percentage of phosphorus in the plant from the rock phosphate than from superphosphate. With legumes, as is true with other crops, if any treatment or source reduces the phosphorus in the plant to the critical level, the yield will be reduced. If a treatment or source does not reduce the phosphorus to a critical level, however, the relative ineffectiveness of the treatment or source is not significant as far as crop production is concerned.

A comparison of rock phosphate and superphosphate in a red clover, corn, and wheat rotation conducted for 20 years revealed it is necessary to apply somewhere between 3 to 7 times as much phosphate in rock in order to obtain a response equal to that obtained from superphosphate (9). Red clover was somewhat more efficient in utilizing the highest rate of rock phosphate than was corn or wheat.

In Alabama, rock phosphate when used in amounts to give twice as much phosphorus as furnished by superphosphate was much less effective in increasing yields of winter legumes, corn and cotton than was superphosphate (2).

Summary

1. The efficiency of the various sources of phosphorus varies considerably.
2. This efficiency is affected by the acidity of the soil. The more insoluble sources are more available on the acid soils.
3. The efficiency is affected by placement. Band placement brings about increased uptake from the more soluble sources.
4. Crops vary in capacity to utilize the more insoluble sources.
5. Under the conditions in the Southeast, superphosphate is a satisfactory all-around source of phosphorus.

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GENERAL COMMENTS ON PHOSPHATES

VINCENT SAUCHELLI[*]

Referring to Prof. Lang's eulogy of the C. G. Hopkins legacy on phosphate thinking at the Illinois Station, may I say that his presentation is by no means shared by many of his confreres on the research staff at that Institution. Hopkins was a remarkably strong character and in his day did a marvelously good job of getting farmers interested in sound practices. But a great deal has been learned since his time both here and abroad about the relative merits of different sources of phosphorus and the interrelationship in the soil between phosphorus and many of the other nutrients. Dr. E. E. DeTurk, Dr. R. H. Bray, and Dr. L. T. Kurtz, of the Illinois Station, have given much serious thought to these problems and have published their research which is at some variance with Prof. Lang's main thesis.

World agriculture, it seems to me, has given a definite answer regarding the relative merits of rock phosphate for direct application and superphosphate: during the last year about 20 million tons of superphosphates were consumed in world agriculture as against a total of about 800,000 tons of rock. That has been about the proportion for many years. In our own country Illinois has been the only state that has consumed rock phosphate for direct application in significant amounts. There must be a reason why farmers persist in preferring processed phosphates to the raw material. I suspect that reason has to do with profitable returns.

Now, to discuss briefly some other items bearing on phosphates.

Because of the close interrelationship among the several branches of agricultural science and the growing complexity in the relationship of all known plant nutrients, it is necessary for workers in this field to broaden their knowledge by going beyond their individual domain. All of us should at least have some acquaintance with the purpose and techniques of workers in other allied fields. The chemist and physicist have been able to help solve problems in the biological field, and the biologist in turn can contribute something to the others. Yesterday's program on methods emphasized this: even though it did make us all aware that ions, spectroscopes, amperes, voltages, photometers, aspergillus niger—the concepts and tools of the chemical, physical, and biological laboratories—can be used as a team, or group approach to solve a common problem. Last week in Baltimore at a symposium on copper at Johns Hopkins, the same thing was illustrated—representatives of the various branches of science

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met to discuss the many interrelationships of this element to soils, plants, animals, and humans.

The importance of fundamental research as contrasted to applied research is being recognized by all major industries as a safeguard to their future. It has been my purpose on many opportune occasions to point out to scientific groups that the fertilizer industry is indeed interested in and fosters fundamental research. This has been revealed in diverse ways, but primarily by establishing fellowships at universities and institutions and by outright grants-in-aid with no strings attached, for the sole purpose of pushing back the frontiers of agricultural science.

One of these manifestations is represented by the creation and purposes of the Fertilizer Industry Committee on Radioactive Research, to which your Chairman alluded. This Committee was organized in the fall of 1946 and is still functioning, and represents a good cross section of the miners, processors, and mixers of the American fertilizer industry. It came into existence because some forward-looking men in the industry whose imagination had been excited by the atomic events of that period believed that this new power which burst so dramatically upon the world could and should be utilized in agricultural research. A generous fund was contributed to get a training program started as a joint project between the industry and several state and federal research agencies. The results of the first year's work attracted much attention, even though it was only a beginning. Men had to be trained in the new tracer technique, instruments had to be purchased. The able leadership of such men as Drs. Dean, Hendricks, and Parker, of the U.S.D.A., Bureau of Plant Industry, at Beltsville, enabled the project to get off to a good start. Dr. Nelson is one of the early workers on that program. From that initial effort the project has now grown to include this year about 20 agricultural experiment stations in this country and one in Canada. The tracer technique is being used extensively on all major soil types and cash crops to find out the most efficient methods of fertilizer placement and the relative advantages of different plant food sources and how plants utilize soil and fertilizer phosphorus. In most of these investigations radioactive phosphorus is used simply as a tracer. Remember, this technique supplements, not supplants, the other techniques of the chemical, physical, and biological sciences. This project represents a splendid cooperation between industry and governmental research agencies and shows what can be accomplished in the best interests of both parties by such joint efforts. May we have more similar programs in the future.

Problems involving soil phosphorus, the use of phosphatic fertilizers, and the phosphorus nutrition of plants are many and exceedingly complex. To begin with, the chemistry of the phosphoric acids itself is complicated; then we introduce phosphates into a wide range of soils differing in clay, humus, iron,

and aluminum, pH, and other factors. As if these problems were not enough, we multiply them by introducing living plants into the system, plants which differ widely as to phosphoric acid and other nutritional requirements. Is it to be wondered at that the field for more intensive research in this dynamic soil-nutrient-plant system continues to challenge all branches of agricultural science? Much has been accomplished; vastly more needs to be achieved. Atomic energy to solve many of these problems, is an ever present hope.

We are assembled here in this great state of Florida. It is only proper that I, representing one of the local phosphate rock miners, should call your attention to Florida's place in the phosphate world. The fertilizer industry is celebrating this year its 100th anniversary of the manufacture of mixed fertilizers. Starting in England, a little over a century ago—1843 to be specific—the superphosphate industry was gradually expanded into a world-wide service industry producing upward of 20 million tons of the product a year. The fertilizer industry is founded on phosphates. Our own domestic superphosphate industry has facilities for producing at the rate of 14 to 15 million tons of normal superphosphate per year. The last year of record it produced about 11 million tons of 20% superphosphate or its equivalent. The great bulk of phosphate rock used in that production came from mines in this state. Since 1880 Florida has been the most important source of supply. The mining industry starting here as a manually operated, pick and shovel operation, has grown into one of high efficiency, utilizing modern power-operated facilities such as many of you saw in last night's tour. It does an amazing job to provide the American farmer with low cost phosphate.

It may be pertinent to review briefly some aspects of fertilizer phosphorus and soil problems of the country. Most of you are familiar with these. For example, the most phosphorus deficient area is in the Coastal Plain soils of the South Atlantic and Gulf Coasts, where the average content of P_2O_5 in the virgin condition of the surface foot of soil was estimated at from 0.0 to 0.4 per cent. This average increases as we go to the north and west. Although total phophorus is not a good index of the phosphorus fertility situation, it gives us some idea of possible reserves. Phosphorus may exist in a soil as a primary mineral, as phosphorus absorbed on the clay surface, and as organic phosphorus. Of these, the absorbed or exchangeable form and the organic phosphorus are important for immediate use by plants.

Now, we know that Phosphorus is being removed by crops and particularly by erosion, and some is replenished by fertilizers, crop residues, and animal manures. We also know from certain surveys that apparently more phosphorus is being returned to the soils in the South Atlantic States than is removed by all

harvested crops. Florida is particularly high in this respect. At one time some folks seriously considered government action, I believe, to reduce the amounts of fertilizer phosphorus being applied. Fortunately that did not happen. These survey data have to be interpreted intelligently. Farmers apply it in heavy amounts because they find it pays. The use of phosphorus or any other plant nutrient is to be related to its money return rather than to the amount removed by crops. Field tests here and in other areas of the humid region show conclusively that it is profitable to put on several times as much phosphorus as is removed by cotton, potatoes, tobacco, and alfalfa, and other cash crops. And general averages do not mean much; we know that farmers do not all put back the phosphorus on their soils to the same degree, the amount varies from farm to farm and from county to county.

Well, to refer again to the radioactive studies, the tracer technique is another tool with limitations like all similar techniques. The radioactive phosphorus does not remain radioactive very long. Its radioactivity may last, say 5 to 6 months at the most, enough for one season's study. It is of no value to determine residual effects of phosphorus fertilization. Other methods must be employed for this phase and we know that most, if not all, of the residual fertilizer phosphorus does remain available despite "fixation." Because of the highly developed phosphate mining and processing facilities in this country, the American farmer is assured a supply of phosphoric acid adequate to meet his constantly growing needs. And the American public can be thankful that this nutrient, so essential to his health, vigor, and well-being, is being made available in generous quantities at all times by the American phosphate and fertilizer industry. Florida may be the Sunshine State; it seems to me it should also be equally proud of and proclaim to the world its unique position as the Phosphate State.

II. A REVIEW OF TRACE ELEMENT RELATIONSHIPS TO AGRICULTURE

A. METHODS OF ANALYSIS

CHEMICAL METHODS FOR DETERMINING TRACE ELEMENTS IN PLANTS AND SOILS

W. O. ROBINSON

MAJOR ROBINSON

The determination of the trace or minor elements in plants and soils, whether by spectrochemical or by chemical means calls for the utmost skill and patience. It is really an expert's job, to be most meticulously performed with simple and transparent honesty. Trustworthy determinations of such small quantities as a few parts per million, especially tenths of a part per million, which in the cases of iodine, cobalt, and molybdenum are significant, require a sound background of theoretical analytical chemistry and laboratory experience, with constant checking by independent methods when possible, and constant vigilance in testing for blanks, and purity of reagents and for contamination by sampling, grinding, and even by constituents of the air before and during the analyses.

Standard Samples

How is the chemist, or spectrographer for that matter, to know that his results are reliable? He can attempt to recover a known quantity added to a sample. But this is not always as

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Note—A quite detailed statement by Mr. Robinson is to be found in the appendix of this volume, pp. 270-278, concerning "The Minor or Trace Elements in Soils, Plants and Animals" that was released in mimeographed form by his Bureau in the U. S. Department of Agriculture shortly before the Winter Haven meetings.—Ed.

simple as it seems and there are serious complications. Obviously the best way is to establish standard samples that have been analyzed by competent analysts and by different methods, if available.

For many years the American Association of Official Agricultural Chemists has had a system of referee standard samples that were sent out to collaborating members, mainly to try out various proposed methods of analysis. As a result this Association has its Book of Methods published every five years. In this book the main emphasis is on fertilizers, food and drugs. Methods of analyses of plants and soils are not so well developed, especially for the trace elements.

I believe that standard samples of plants and soils, prepared especially for their contents of manganese, boron, copper, zinc, lead, molybdenum and such other trace elements that may develop, to be important to agriculture. It is important, of course, that the major element contents of such standard samples be known, and also that contamination by sampling, grinding, and storage be reduced to a minimum. Such standard samples, as authentic as the National Bureau of Standards samples of industrial products and materials, should be available to analytical chemists and those engaged in quantitative spectroscopy in the field of agronomy. To serve best, these standards should be international in character. The Soil Science Society of Florida might well take the leadership in this matter, as they have long recognized the desirability of such standards.

Specific Methods

For the determination of copper, zinc and lead, most chemists prefer the dithizone method. This process is described in detail by Sandell (8), A.A.O.A.C. Book of Methods (6) and Holmes (4). It is our experience that the mechanical shaking device described by Holmes and Mullins (5) contributes a lot to the reproducibility and reliability of the method. The extreme sensitivity of this method imposes penalties. The sample is small and must be well mixed and finely ground. Constant vigilance is needed to guard against contaminations. It is not an easy method. Some have preferred to estimate zinc with the polarograph after separation from interfering elements by dithizone.

A concrete example of the importance of accuracy in analysis and of establishing standard sample may be illustrated by giving in detail the data on the occurrence of molybdenum in plants and soils that have been accumulated.

It seems probable that the chromograph technique as described by Stevens and Lakin (9) for geochemical prospecting could be used for some of the trace elements. They have successfully used the chromograph in locating nickel and copper bearing formations by testing samples of the overlying soils and plants.

Nichols and Rogers (7) have compared the spectrographic, colorimetric and polarographic methods for determining molybdenum. Their conclusion was that the colorimetric thiocyanate method is preferable except when only very small quantities are available. They report very high molybdenum in a sample of para grass, 310 to 370 parts per million. Results for other vegetation range between 19 and 57 p.p.m. Since Nichols and Rogers published this work in 1944 the colorimetric method has been improved by the addition of very small quantities of solutions of ferric iron and potassium nitrate before the development of the color.

Molybdenum in Soils

We have made molybdenum determinations in over 300 United States soil samples, mostly profile samples, and results range between 0.7 p.p.m. in Vernon fine sandy loam, Guthrie, Oklahoma, to 31.6 p.p.m. in DeKalb silt loam, Bloom, Virginia. This is by far the highest. There was only one area where the molybdenum was anywhere nearly as high and this is on an experimental plot of Cecil clay loam near Raleigh, North Carolina. Over ninety percent of the determinations of molybdenum made range between 1 and 4 p.p.m. This relatively constant quantity of molybdenum in United States soils examined would seem to point to some biological factor tending to keep the molybdenum content of soils up to a certain level.

The above relative constancy with regard to the molybdenum content does not seem to hold for soils in other parts of the world. Dr. H. C. Trumble, now with Food and Agriculture Organization recently sent in three soils from Nicaragua. He learned it had not been possible to grow legumes on soils Number 1 and 2. However, legumes could be grown on soil Number 3. He immediately suspected molybdenum deficiency in Soils 1 and 2. In these two soils there was only the merest trace of molybdenum, if any at all, but No. 3 had 2.4 p.p.m. In Somerset, England, the soils of the "teart" lands contain up to 100 p.p.m. Mo. One soil from Puerto Rico, the Nipe, contained 20 p.p.m. in the surface horizon with average quantities only in lower horizons. A similar concentration occurred in the surface of an Hawaiian soil. This condition, however, is not always the rule with tropical soils, as several profile samples from Australia and Belgian Congo show only average molybdenum and no concentration on the surface.

Didier Bertrand (3) has reported European soils, mainly French, relatively very high in molybdenum. Twenty soils ranged from 4.3 to 69.0 p.p.m. Mo. Many of these soils are on Agricultural Institution grounds. Half of these soils are over 20 p.p.m. and the average is 27.8 p.p.m. Mo. This is over ten times the average of soils in the United States.

Molybdenum in Plants

In the analysis of 50 different kinds of crop plants and common weeds (216 samples) on 25 soil locations in Maryland, West Virginia, Indiana and Virginia it was found that there was not a great difference in the molybdenum content of different kinds of plants, though, in general, smart weed and lambs quarters tended to be highest. The extreme ranges are from 0.1 p.p.m. Mo. in lespedeza to 8.8 p.p.m. for red clover on Miami soil in Indiana. The average for 12 samples of red clover was 1.85 p.p.m. Eight samples of smart weed averaged 2.90 p.p.m. All results are based on the dry weight and are for the entire plant above ground. All plants were collected during mid-August. There was not a good correlation between total molybdenum in soil and plant, though there is a distinct tendency for soils high in molybdenum to produce plants higher in that element. The dependence of the uptake of molybdenum by the plant on the reaction of the soil was somewhat better but there were small exceptions. In this, as well as in other studies, legumes were not higher in molybdenum than non-legumes on the same soil except on one site. In many cases non-legumes exceeded the legumes.

The average molybdenum content of 105 samples of alfalfa was 2.70 p.p.m. molybdenum with a range of from 0.1 to 9.4 p.p.m. These samples were from 10 states, and included 20 samples from the Yuma, Arizona, area which were all comparatively high. In this area the soil is comparatively low in total molybdenum. The molybdenum in the plant apparently comes from the irrigation water. Alfalfa from the eastern states is generally much lower in molybdenum than that from western states, but there are exceptions. On a heavily limed plot of Cecil clay near Raleigh, North Carolina, alfalfa had between 7 and 8 p.p.m.

O. A. Beath (1) reports a woody aster plant from the Morrison Formation in Utah which contained 333 p.p.m. molybdenum. Other samples of woody aster from this same formation contain 100 p.p.m. and over. We have analyzed pea seeds from the province of Boyaca, Columbia, S.A. with 91 p.p.m. Mo.

Pasture vegetation on the teart lands of Somerset, England, is reported to contain as high as 100 p.p.m. molybdenum.

Beath, Draize and Gilbert (2) in 1934 were first to point out the toxic action of molybdenum in vegetation on cattle. They also called attention to the effect of molybdenum on bone malformation.

Trace Elements in the Air

In confining methods of analysis to soils and plants we have overlooked the main environment of the plant from which the plant obtains by far the most of its substances. This main en-

vironment of plants is the atmosphere. From this the plant must obtain practically all of its carbon. Carbon, by the way, is just about a trace element in the atmosphere.

There are but 3.5 parts of CO_2 in 10,000 parts of atmosphere or 128 parts per million carbon in the atmosphere. In the vicinity of industrial plants burning coal, the proportion of CO_2 in the air is only slightly increased, as analyses have shown. The tremendous capacity of plants, large bodies of water, particularly the ocean to absorb this CO_2 tends to keep the CO_2 in the air at a constant level. But how about other trace constituents? There are large quantities of methane, volatile sulphur compounds, etc. being continually given off as marsh gas from decaying organic matter. The numerous bubbles arising from submerged organic matter in sluggish streams and ponds is a familiar example to all. This marsh gas consists of carbon dioxide, air, methane, and even hydrogen and carbon monoxide. One may even question if rather volatile and stable organic compounds of the trace elements are not present in some small quantity.

The analytical methods for trace elements in the atmosphere have not been developed. Following damages by smelter fumes and chemical manufacturing some recording devices have been made but they are adopted for relatively high concentrations only. For sometime I have been interested in a device which should give, with some accuracy, very low concentrations of the trace elements in the atmosphere. If a liter vessel built to withstand 1500 lbs. per square inch, were connected with a compressing pump, so that the air could be quantitatively compressed to 1500 lbs. per square inch we would have from 12 to 14 grams of air compressed into the vessel. In most of the humid east the air is over half saturated with water vapor so that, when the pressure inside the vessel reaches 2 atmospheres, minute water droplets form, and in condensing on nuclei, carry down the impurities contained in the air. If the operation is continued to 10 atmospheres there might be formed as much as 0.3 m.l. of water.

The contents of the vessel could then be frozen, and the gases led through a system of impinging plates, and suitable absorption tubes for the desired trace elements or compounds. Ten such fillings would represent roughly 120 grams of air, and might yield as much as 3 m.l. water suitable for the determination of a number of elements by the spectrographer or for sulfur, fluorine and chlorine, etc. by chemical means. No doubt the water condensed by concentration in the first chamber of the compressors of liquid air manufacturers would yield many valuable clues to the presence of trace elements in the atmosphere.

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THE USE OF SPECTROGRAPHIC METHODS IN THE ANALYSIS OF SOILS AND OF PLANT AND ANIMAL TISSUES IN TRACE ELEMENT STUDIES

T. C. ERWIN*

The adaptability of certain physical and chemical methods for determining the trace element content of various agricultural materials was discussed in brief detail by Rogers and Hughes (1) at the time of the first symposium on this subject on the forum of this Society in Gainesville in 1940.

In this review particular emphasis was placed on the usefulness of dithizone extraction methods which were under study at that time and on the adaptability of the spectrograph, especially for exploratory studies in the broad field of trace element relationships to agriculture. The semi-quantitative and the precision procedures as developed at that time for the spectrograph were reviewed. In the meantime both approaches have been considerably improved not only by a more extensive medication of the sample but also by the availability of a much more versatile and accurate microphotometer.

Sample Preparation, Including Pelleting

The definite experience of certain trace element losses during sample preparation both by the wet combustion procedure and by ashing in the usual manner at "controlled" temperatures greatly accentuated our interest in the pelleting of the sample so that it could be placed in its entirety in the arc and burned during the period of normal plate exposure. The above studies included the spectroanalysis of captured smoke samples which showed definite losses of some of the trace elements varying with the type of plant materials studied and the contained elements.

These pellets (¼") were made with a press capable of delivering 80,000 pounds per square inch. Under such a pressure no cementing substance was necessary for any of the materials that it was found desirable to study. For arcing, the pellets were placed in 5/16" cavities formed by a special tool in the carbon electrode.

Some interesting results were obtained and some very definite advantages are thought to be available through the pelleting procedure though a considerable amount of work remains to be

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(1) Rogers, L. H. and Hughes, R. C., Proc. Vol. II, Soil Science Society of Florida, pp. 59-67, 1940.

done with it before it can be regarded as fully routine. The principal trials were made as a rough quantitative procedure by running samples of known levels of the unknown elements under a set of standard conditions as to pellet size and exposure characteristics and then plotting line density and quantity of element curves before running the unknown sample and comparing it with the standard curve. Some of the advantages are, of course, speed thru the avoidance of the tedious ashing procedure and its accompanying dangers of contamination and losses.

While the pelleting procedure is subject to numerous possible errors it was found quite satisfactory, for instance, in roughly determining the molybdenum content of forage samples. Doubtless the greatest source of error is the lack of homogeneity in the plant sample under study as only 1/10 gram of sample was taken for the purpose and this could not be ground or homogenized in any way without quite special equipment. Thus one of the most difficult problems in connection with the pelleting procedure is the preparation of the sample itself, especially in the case of plant parts, in order to insure that a truly representative portion is taken for the small amount that can be included in the pellet.

In the meantime all samples that have been ashed for spectroanalysis have been processed at the lowest possible heat. However, as intimated above, in order to burn to an acceptable ash, samples must ignite at some time or other and they are then exposed to an uncontrolled temperature even though it may be only for a comparatively brief period.

Rough Estimate Procedure

In the rough estimate procedure weighed amounts of the ashed soil, plant or animal materials are burned in the arc in juxta positions on the plate against the spectrum of a synthetic standard containing varying amounts of 30 to 40 elements of potential interest that are detectable on the plate under the conditions of test. In the case of plant materials the base is largely made up of sodium, potassium, calcium, magnesium and phosphate while in the instance of most mineral soils in Florida it is largely silica, depending considerably upon soil type. Of a group of some 34 trace elements so listed for routine examination of plates the limit of detection of 26 of them was placed at 1, 2 at 4, 1 (zinc) at 6 on the large Littrow Spectrograph and at 1 on the Zeiss, 2 at 7, 2 at 8 and 1 at 10.

Thus, by running 2 plates with a proper control, reference estimates can be had on 30 elements or more with the sensitivity varying, of course, for each element. The major elements calcium, sodium, magnesium and potassium can be read as low as 1 p.p.m. whereas the sensitivity of phosphorus is very poor. The operation of this method is shown quite clearly in certain papers

of the Symposium referred to above (2) where many trace element values are reported on soils as well as plant materials.

As the term indicates, the rough estimate procedure lends itself especially well to exploratory or survey types of study. This of course makes it especially useful in such a field as agriculture that involves so many different though closely related materials (soils, fertilizers, plant and animal tissues) and particularly on account of the many complex biological factors that may be involved at different times. Discoveries by this method that have had a tremendous influence on Florida agriculture which might be mentioned must always include cobalt and molybdenum, as well as zinc. The former was first detected by this means as the beneficial element in a particular source of pyrites in New Zealand capable of curing what was known over there as "Bush Sickness," the apparent equivalent of one of our most severe forms of "Salt Sick" in Florida. Likewise molybdenum, an element now to be reckoned with where excesses are to be found in the herbage as, for instance, on some of our organic soils, was first observed in Dallis grass from the Everglades Station with the use of the spectrograph. Again, it was through the use of the spectrograph that zinc was first established as the deficient element in the well known "Frenching" of citrus that has caused very heavy losses to this industry in the past. In this instance it was the small Zeiss unit that was used since it was found to be much more sensitive to this element at the time of these studies than was the large Littrow.

Quantitative Procedure

This procedure consists largely of adding a known quantity of an internal standard to a known quantity of homogenized ash of the unknown. This standard can be any element not found in the sample in appreciable quantity but should be so selected that its excitation characteristics match those of the unknown element(s) as closely as possible. Elements in common use for this purpose are palladium, tellurium and tin.

After thoroughly mixing with the standard, a non-specific quantity of the mixture is burned in the arc in such manner as to give specific lines of reasonable density. The intensity ratios of the unknown to the standard element are then determined by the process of determining line density with the microphotometer and then calculating the correction by plate calibration for background density.

The accuracy of the method is dependent largely on the selection of an internal standard the various characteristics of which match those of the unknown as closely as possible. With

(2) Symposium—The "Trace" or "Micro" Elements in the Service of Florida Agriculture. Proc. Vol. II, Soil Science Society of Florida, pp. 51-115, 1940.

a properly selected pair the method should be reproductible within an error of 5 percent. However, in the interest of speed in the face of large numbers of samples to be studied, and in the need for multiple determinations, the method has been expanded to compare as many as six unknowns with one internal standard. Certain errors developed in setting up this procedure but these were determined largely to be due to definite variations in the excitation temperatures of the standard element and the unknown.

In consequence of these trials it was determined that for all practical purposes most of the elements of interest in this field could be placed in one of three groups where any element in the same group would serve as a suitable standard for any other of the group. These groups were formed by establishing the amount of excitation that developed in individual elements at various times during the arcing. Thus, one group, well represented by copper and tin, burns early since only a comparatively low temperature is required for their excitation. A second group, instanced by calcium, has a rather constant degree of excitation during the entire period of burn. A third group, e.g. aluminum and beryllium, requires the highest temperature and its members are, therefore, the last to appear on the plate.

It has been found that to develop the highest degree of accuracy, advantage must be taken of the use of double (e.g. copper and tin or iron and palladium) and even of triple standards. In this case particular care must be used in the selection of the standards to get them from the same excitation group since we now know that failure to match in this respect can prove the greatest source of error. In addition to the above and in order to attain greatest accuracy the lines of the unknown and of the internal standard should be of approximately the same wave length and the plate calibration curve must be run at that wave length. Therefore a series of plate calibrations will be necessary for best accuracy in different regions of the spectrum. With good care in the handling of all these limitations, errors as low as 5 percent should be attainable.

Summary

The principal trace elements of interest to Florida Agriculture and to which most attention is being given at the present time are seven in number, namely copper, manganese, cobalt, zinc, iron, boron and molybdenum.

The place of the spectrograph in any comprehensive study of these and other trace elements in such a complex biological field has been well established though the methodology of the approach is constantly in need of improvement.

While the outstanding individual findings to date in this field in Florida thru the use of the spectrographic technic have been

cobalt in relation to "Salt Sick," molybdenum in certain muck grown forages in relation to scouring of cattle and the consequent need for extra medication with copper, and the deficiency of zinc in relation to citrus "Frenching" under certain conditions, it also has helped tremendously in the study of certain interrelationships of these elements in the animal body such as that of cobalt intake in the steer to a much more favorable storage of copper in the liver of the animal under otherwise identical conditions. Its extensive use in the routine analysis of soil, plant and animal samples also has helped immensely in the handling of many problems and it doubtless will be of even greater assistance in the future if requisite time and effort are given to the improvement of the methods presently in use.

POLAROGRAPHIC ANALYSIS FOR MINOR-ELEMENTS IN PLANTS

W. L. LOTT*

Applications of minor-elements to correct abnormalities in plants were studied as early as 1927 in North Carolina by L. G. Willis (7). Despite these early beginnings, there is little definite information as to the frequency of occurance of minor-element deficiencies and the soil types involved. The use of plot tests for locating sites where crops respond to applications is obviously tedious and expensive. Surveys by foliar analysis seem likely to be more efficient in finding deficiency areas. A survey of this kind was carried out in 1948 in connection with studies of the mineral nutrition of strawberries. Leaf samples were collected from 300 commercial fields for determination of copper, zinc, manganese, and magnesium. The analytical procedure developed for this work included the use of the polarograph for copper and zinc. Aspects of these determinations will be discussed here.

Leeds and Northrup Company (2) have just released a bibliography of polarographic literature, containing 2208 references. Relatively few are concerned with the analysis of biological materials. Thus, of seventy-five on copper, only nineteen are for biological samples. For zinc, fifteen of ninety-one articles are concerned with biological materials. For manganese, there are two; for cobalt, two; for molybdenum, one; and for boron, none.

In the United States, microgram quantities of copper have in most instances been determined by colorimetric methods, the most popular of which have utilized "dithizone" or sodium diethyldithiocarbamate as color-forming reagents. Many procedures have employed dithizone for segregating the trace-elements before measurement by other means. Reed and Cummings (5) however, for a polarographic method, removed interfering iron and aluminum by precipitation with an excess of ammonium hydroxide. The filtrate containing copper was evaporated to dryness and the residue dissolved in a supporting electrolyte of acid sodium citrate for obtaining polarograms. In a similar procedure for zinc by the same authors (4) the iron and aluminum were precipitated by adjusting the solution of plant ash to pH values between 4 and 5. The filtrate was evaporated to dryness and the residue dissolved in a supporting solution of ammonium acetate and potassium thiocyanate for making polarograms. These precipitation methods of separation, despite their simplicity, have evidently not been used widely by other workers, probably because of the opportunities for losses by absorption on the precipitates, and contamination from the filter paper.

Typical methods employing dithizone to isolate zinc for determination by the polarograph are those of Takazawa and Sherman (8) and of Walkley (6). Holmes (1) published a method

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for the determination of zinc, cobalt, copper, and lead in soils using dithizone. Copper was extracted at pH 2.5 (thymol blue) and zinc was then extracted from the same solution after the pH value was adjusted to 8.3 (thymol blue). Both zinc and copper were measured by means of the colored dithizone complexes.

For the strawberry foliar analysis survey mentioned earlier a procedure was sought which would permit the determination of both copper and zinc in aliquots of the same sample. Holmes method seemed promising for isolation of the two elements, but was found unsuccessful due to the fact that about one-third of the zinc in the sample was extracted with the copper at pH 2.5, giving low values for zinc from the subsequent extraction at pH 8.3. This difficulty was surmounted by extracting both zinc and copper together at pH 8.3, diluting to known volume, and using separate aliquots of the extract for copper and zinc, respectively. It would be advantageous to determine both zinc and copper polarographically in the same solution, but no supporting electrolyte has been found which permits the determination of both metals in the same solution at the low concentration levels found in plant samples. The convenience afforded by such a solution to support polarograms of copper at 2 to 8 micrograms and of zinc at 7 to 30 micrograms per milliliter would justify the expenditure of considerable time and effort directed toward its discovery.

Reed and Cummings (5) observed that copper was lost from plant tissue samples during dry ashing, and recommended that perchloric acid digestion be used instead, no losses being occassioned by this procedure.

In the light of the foregoing considerations, the following procedure was developed and found satisfactory for foliar analysis of strawberry, the results of which have served to locate fields which were later shown to be definitely deficient in copper.

The fresh leaves were rinsed free of adhering soil by means of water redistilled from a Pyrex glass still, with light scrubbing of the leaf between finger and thumb where necessary, followed by rapid rinsing in two changes of re-distilled water. The excess moisture was shaken off and the leaf blades dried in an oven with forced circulation at 80 degrees centigrade. The dried leaves were ground in a small Wiley mill having no brass or bronze parts.

Two-gram portions of the sample were weighed into 50 ml. Kjeldahl flasks fitted with ground glass stoppers and having calibration at 50 ml. Two ml. of conc. nitric acid was added to each flask, which was then placed in a beaker on a warm hot-plate. When reaction had slowed somewhat, 2 ml. more of nitric acid was added and the heating continued. A third 2 ml. portion of nitric acid was added followed immediately by 2 ml. of 60% perchloric acid. The temperature of the hot-plate was gradually increased until oxidation of the organic matter was complete, leaving a colorless solution. Occasionally the digest would char somewhat, near the end of the digestion. The addition of two drops of con-

centrated nitric acid served to discharge the brown color. In some cases this color reappeared and was discharged by further 2-drop portions of nitric acid until finally the digest became permanently colorless.

To the cooled digest in the flask was added 10 ml. of water, which was then boiled for a few seconds by heating over a gas flame (with agitation to prevent bumping) to expel free chlorine and to dissolve the salts present. After cooling, the solution was diluted to 50 ml. and 40 ml. aliquots transferred to a 200 ml. separatory funnel. The remaining ten ml. was used for determination of manganese and magnesium. To the solution in the funnel was added 3 ml. of 50% ammonium citrate and five drops of 0.05% thymol blue. Ammonium hydroxide was added until the red solution changed through yellow to blue. Five ml. of 0.2% dithizone in carbon tetrachloride were added and the funnel stoppered and shaken vigorously for one minute. The funnel was then allowed to stand until the solutions separated (five minutes) and the carbon tetrachloride layer was drawn off into a 25 ml. volumetric flask. The extraction was repeated with two more 5 ml. portions of dithizone solution, and the three extracts were collected in the same flask and diluted to 25 ml. with carbon tetrachloride.

A 10 ml. aliquot was withdrawn and transferred to a 20 ml. pyrex beaker for the determination of zinc. The carbon tetrachloride was evaporated by gentle heating on the hot-plate. To the dry residue in the beaker was added 0.5 ml. conc. nitric acid, 0.5 ml. 60% perchloric acid, and two drops conc. sulfuric acid. The temperature of the hot-plate was gradually raised until only the sulfuric acid remained in a fuming state. The beaker was transferred to a muffle furnace at 400 degrees centigrade for five minutes to expel the remaining sulfuric acid. At this point zinc and copper sulfates remained as a faint white residue in the bottom of the beaker. The latter was cooled and exactly one ml. of supporting electrolyte (6) (0.1 N NH_4Cl, 0.02 N KCNS and 0.0002% methyl red) was pipetted into it, bringing the solution in contact with the sides of the beaker. After standing for 3 to 5 minutes, the solution was poured into an electrolysis vessel and the latter was connected to the polarograph. Pure nitrogen gas was bubbled through the solution for 3 minutes. The polarographic current-voltage curve was then plotted for the range −0.75 volt to −1.4 volt. Known amounts of zinc sulfate (0 to 30 micrograms of zinc) were evaporated to dryness in 20 ml. beakers and taken up in supporting solution for plotting polarographic curves to produce a calibration curve of wave height versus concentration of zinc. From this graph, the levels of zinc in the samples were then read. Subsequently, two or three standards (20 micrograms of zinc) were run with each lot of 12 samples, to check the validity of calibration.

Copper was determined in the remaining 15 ml. of dithizone extract by transferring it to a 20 ml. beaker and converting the

metals to sulfates exactly as for zinc above. The cooled beaker containing the sulfates then received 1 ml. of the supporting electrolyte of Reed and Cummings (5) (equal volumes of 0.5 M NaOH and 0.5 M citric acid plus 0.005% acid fuchsin). After 3 to 5 minutes of contact with the beaker, the solution was transferred into a polarographic cell, de-oxygenated with nitrogen gas for 3 minutes, and the current-voltage curve plotted for the voltage range 0 to —0.6 volt. Known amounts of copper sulfate evaporated to dryness in 20 ml. beakers served as standards for ascertaining wave heights and these were plotted against concentration of copper in the solutions electrolysed. From this graph, the quantities of copper in samples were read. As for zinc, two to three standards (5 micrograms Cu) were run with each lot of 12 samples.

The procedures described here have served to measure quantities of copper ranging from 2 to 8 micrograms and of zinc ranging from 5 to 25 micrograms from samples of plant material. Precision of these determinations was found to lie within 10% of the amount of the element being determined and commonly averaged about 5% for determinations carried out on the same sample on different days.

Purification of reagents, where necessary was carried out by the methods described by Piper (3). Perchloric and sulfuric acids of C. P. grade were found to be sufficiently pure. Hydrocloric acid and ammonium hydroxide were redistilled from Pyrex. Ammonium citrate was extracted with dithizone. Carbon tetrachloride was re-distilled when test showed the presence of intolerable impurities in a given lot. Dithizone solutions were prepared according to Piper. Commercial nitrogen gas was used without purification. With these precautions, blank determinations commonly yielded about 0.3 microgram of copper and 1.0 microgram of zinc.

Sample values were always corrected for the quantities found in the blanks which were run with each lot of 12 samples.

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THE ADVANTAGES OF THE FLAME PHOTOMETER IN SOIL AND PLANT ANALYSIS

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Although the flame photometer, to a certain extent, is more limited in its application than the spectrograph, it is finding wide acceptance as an instrument for the determinations of sodium, potassium, calcium, magnesium and manganese in solutions containing these elements. With improved electronic circuits and better burners its use soon may be extended to include more of the minor elements, such as copper.

In the soil testing laboratory the flame photometer will quickly pay for itself by the time saved in determinations of potassium. Analyses for this element by the cobaltinitrite precipitation methods require considerable time while the more rapid turbidimetric procedures are entirely unsatisfactory unless temperature and other conditions during manipulation are very rigidly controlled. Even these methods, especially the latter, lose their required accuracy at low levels which are usually encountered with samples of soils low or deficient in potassium. With a flame photometer a single operator may develop the skill and technique which will allow the determination of potassium on as many as 100 soil extracts per hour. Furthermore, the results usually are found to be reproducible even at very low levels of potassium.

Tests made on a Beckman flame photometer equipped with the original type, large, metal burner with chimney indicate some slight interferences in the excitation of one element by another, but not sufficient to introduce errors which might be objectionable in routine soil tests. Sodium may increase the reading of a 15 ppm. potassium standard approximately 6 percent at 25 ppm. of the element and as much as 20 percent at 90 ppm. Such high values for sodium are seldom found in soil samples under conditions usually encountered in South Florida. Calcium up to levels as high as 3000 ppm. showed no effect on the excitation of potassium with a standard containing 15 ppm. potassium. Magnesium up to 150 ppm. showed no effect on the same standard.

Sodium, potassium or magnesium at the highest levels usually found in soil extracts showed no effect on calcium determinations ranging from 0 to 1500 ppm. Sodium, potassium or calcium had no effect on magnesium readings. Preliminary tests with manganese indicate no pronounced effects due to the presence of sodium, potassium or calcium at the highest levels normally present in soil extracts.

Considerable time in converting the readings to ppm. or pounds per acre in the sample may be saved by adjusting the slit width

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and sensitivity for each set of readings in such a way that two standards representing positions on the curve will read approximately on the predetermined standard curve. By following this procedure the sample readings may be converted to the desired values by reading directly from tables prepared from the original standard curve. These standard tables may be used indefinitely without recalibration. Such a procedure is well adapted to routine soil testing where speed may be a more important factor than quantitative accuracy.

The flame photometer is equally well adapted to extracts of fresh plant tissue and solutions of soil or plant ash. The same solution should be used for extraction of the tissue or dissolving of the ash samples as is used for the standard solutions. This also may be the same solution used for extracting soil samples, thus making the same standards applicable to all types of analyses.

Flame photometry has contributed a great deal to the speed and accuracy of chemical analyses and no doubt will find wider fields of application as improvements are made in the design and operation of the equipment.

A MICROBIOLOGICAL ASSAY FOR AVAILABLE BORON IN SOILS

S. N. EDSON, A. F. NOVAK, F. B. SMITH[1]

It is generally agreed that correlation of chemical soil tests and actual crop requirements leaves much to be desired. This appears to be particularly true for boron. A partial explanation in this instance is indicated by the fact that boron may not be absorbed by the soil colloid like copper or zinc ions. A very slight application of borax above that needed by plants causes injury (13). Recognizing this, Schuster and Stephenson (10) developed the sunflower-pot-culture test for boron deficiency in soils. Results from this test are satisfactory but the method is time consuming and expensive. Steinberg (11) suggested the use of fungi to determine the essentiality of minor elements because of the similar physical and biochemical relationships of these microorganisms to the higher plants. Mulder (8) demonstrated this possibility earlier with his *Aspergillus niger* test for available copper in his investigations on the "reclamation disease" problem in Holland.

From 1939 to the present date, the occurrence of boron deficiency has been observed, especially in the sandy soils of the coastal plains.

Jones and Scarseth (4) observed that high lime soils required more boron than acid soils and that applications of lime limited the availability of boron to plants. Midgely and Dunklee (7) found that calcium, barium, magnesium, and sodium carbonates were equally effective in fixing borates in soils, which strongly suggested that reaction may be the controlling factor in boron fixation. These workers demonstrated that boron fixation in alkaline soils was of a temporary nature. Naftel (9) suggested that liming soils stimulated microbiological activity to the extent that available boron is depleted. Hanna and Purvis (3) substantiated this claim to some degree by showing a rapid rise in carbon dioxide evolution when either lime or boron was added to acid soils. They proposed the use of this phenomena as a biological test for boron, and found *Trichoderma viride* to be especially sensitive to these changes

Marked response to boron by various species of *Penicillium* was shown by Koffler et al. (6) while investigating the possible use of boron to increase penicillin yields and inhibit bacteria. *Penicillium chrysogenum*, Strain NRRL-1951-B25 was especially sensitive to various boron levels.

The purpose of this investigation was to develop a micro-

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biological assay for available boron in soils. Studies on the practical application of the method are being continued.

Experimental

Selection of Soils and Determination of the Approximate Boron Content

Random samples of Lakeland fine sand were taken from various locations in Alachua County where the soil was known to be deficient in boron. The approximate boron content of four samples of this soil was adjusted by treating with sufficient borax to roughly simulate deficient, adequate, abundant, and toxic conditions. A final analysis of the soils was made by the mannitol-titration procedure (2) to establish an approximate boron rating for the different samples. The results are tabulated as follows:

Table 1.

Approximate Boron Rating of Four Samples of Lakeland Fine Sand (Chemical Method)

Sample	Rating	p.p.m. Boron
A	Deficient	Trace
B	Adequate	0.2
C	Abundant	0.5
D	Toxic	0.9

Methods of Procedure

A standard complete mold nutrient medium was selected that had been tested in actual practice. Barton-Wright's (1) modification of Stokes' medium was used, principally because it contained all factors that permit a rapid development of mycelium and little or no sporulation (12). These factors include organic acids and a high Zn content, in addition to sources of Na, Cl, Mg, and Ca not commonly found in other media.

The optimum growth range for both *Penicillium chrysogenum* and *Trichoderma viride* was established by plating out these molds at 0, 0.1, 0.25, 0.5, 1.0, 3.0, and 6.0 p.p.m. of boron, using Barton-Wright's medium plus 2% of washed agar. This procedure was repeated, using 10% $CaCO_3$ in the medium, which brought the reaction from pH 4 to pH 6. The latter step was instituted in order to note any changes in the response to boron because of the weaker acid condition.

The representative unknown sample of soil was depleted of boron by saturating an amount of dry soil with C. P. methanol (5). In the absence of water, H_3BO_3 forms volatile esters with the alcohols. Fixed or slowly available amounts of boron were

not considered in this study, since the readily available and not the fixed or slowly available amounts of boron was the object of this investigation. This procedure was considered satisfactory for all general purposes.

In order to prevent any major chemical changes in a standard medium, especially when subjected to the heat necessary for sterilization, only 1 gm. of soil to 10 ml. units of nutrient was used. The small amount of soil in proportion to the large amount of nutrient was further selected because it was desirous that the buffer capacity of the medium remain unchanged in case soils of high alkalinity were tested.

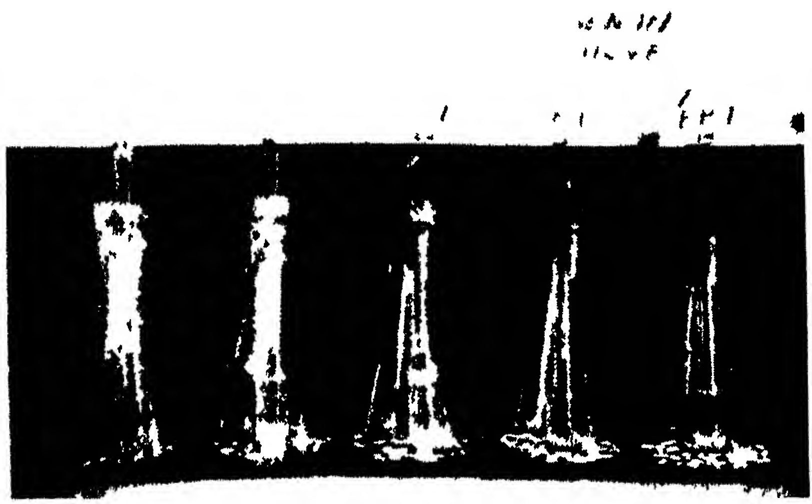

Figure 1.—Culture flask setup for absorbing CO_2 evolution in KOH solution during incubation

For the final procedure, 250 ml. flasks were selected for the boron response series as well as for the duplicate unknown. The prescribed amounts of soil and nutrient were added and each flask marked as to its boron content. After autoclaving, inoculation, and incubation, the variation in the amount of mycelium produced by the different boron levels was considered to be proportional to the amount of CO_2 evolved (3). With this in mind, the CO_2 was measured by absorbing the gas in 10 ml. of 0.5 N KOH solution, which was conveniently added through a large tube (Fig. 1) at the mouth of the flask, prior to incubation. After a specified period of time, an excess of 2N $BaCl_2$ was added to each flask, and the free alkali titrated directly with 0.5 N HCl using thymol blue indicator. The entire procedure was performed without moving the test tube from the

flask. The mls. of standard acid needed to arrive at a definite yellow color was plotted directly on a graph to represent a growth curve. The results from the unknown sample were obtained in a similar manner and interpreted on the standard curve.

Results

All plates were incubated at 28 C. At the termination of 72 hours, only *Penicillium chrysogenum* exhibited any boron response in the acid series. For the Ca-treated series, both of the molds showed as much as 100% increase in growth and a definite response to boron. Within a few hours later, both molds quickly overgrew the plates, revealing that only the initial growth period appeared to be affected. The greatest variation to boron in the acid series occurred between 0 and 1 p.p.m.

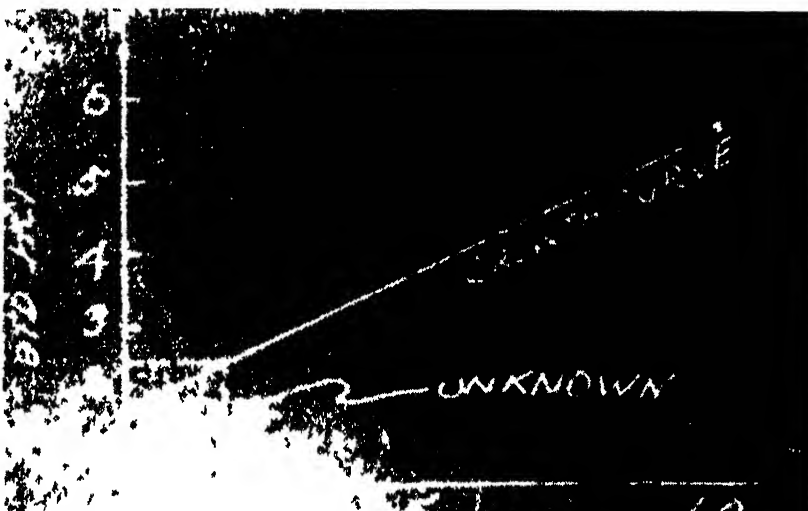

Figure 2.—Growth curve based on titration values showing CO_2 evolution during period of incubation.

From 1 to 3 p.p.m., there was a slight variation and the actual inhibition at 6 p.p.m., indicating an optimum at about 3 p.p.m. of boron. For the $CaCO_3$ treated series, the same conditions occurred, except the optimum changed to near the 6 p.p.m. boron level. This appears to substantiate the claims of earlier workers. For the final results, it was decided to use *Penicillium Chrysogenum* in an acid medium with a range from 0 to 1 p.p.m. of boron.

A standard growth curve was made by using five 250 ml.

flasks containing 0, 0.1, 0.25, 0.5 and 1.0 p.p.m. of boron, respectively, and following the procedure described above. Inoculation was accomplished by adding one drop of a heavy spore suspension of *Penicillium chrysogenum* to each flask. After 72 hours, a definite visual difference was apparent in the number of colonies corresponding to the different amounts of boron present in the flasks. After titration, the standard growth curve was plotted (Fig. 2) and the duplicate unknown sample referred to this curve for determination of readily available boron.

The results obtained are presented in Table 2 for comparison by the chemical method.

TABLE 2

COMPARISON OF BORON RATING OF FOUR SAMPLES OF LAKELAND FINE SAND BY BIOLOGICAL AND CHEMICAL METHODS.

Sample	Boron Rating	p.p.m. Boron	
		Biological	Chemical
A	Deficient	Trace	Trace
B	Adequate	0.1	0.2
C	Abundant	0.2	0.5
D	Toxic	0.5	0.9

SUMMARY

A preliminary study of a microbial test for available boron in soils is reported. *Penicillium chrysogenum*, strain NRRL-1951-B25, appeared to be superior to *Trichoderma viride* in its response to boron.

The addition of 10% $CaCO_3$ increased the growth of both molds as much as 100% and increased the optimum boron response from 3 to 6 p.p.m. The greatest variation appeared to be from 0 to 1 p.p.m. of boron; this occurred within a narrow range of 50 to 72 hours. Thereafter, the growth quickly equalized in all flasks. The medium changed from acid to alkaline conditions, probably due to the loss of carboxyl groups by excessive CO_2 evolution and the accumulation of the basic ions that do not enter to any extent into the structure of the tissue.

The investigation indicates that many soil fungi may be similar to higher plants in the variation and response to boron.

Penicillium chrysogenum was found to respond to various levels of boron under similar conditions of physical and chemical environment. This response was determined by the number of colonies present in the flask and by the amount of CO_2 evolved. This method appears to have merit as a microbiological assay for boron in soils.

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B. TRACE ELEMENT RELATIONSHIPS TO THE HEALTH AND GROWTH OF PLANTS AND ANIMALS

TRACE ELEMENT RELATIONSHIPS OF THE NORMAL GROWTH OF AGRICULTURAL PLANTS ON THE *ORGANIC* SOILS OF FLORIDA

R. V. ALLISON[k]

It is an interesting fact that at precisely the same time the first systematic studies of trace element relationships to plant growth on the organic soils of the Everglades were begun at the Everglades Experiment Station (Spring, 1927) the Brown Company of Portland, Maine and Berlin, N. H., made their first "test planting" of 1,000 acres of peanuts on identically the same type of soil on their extensive plantation, then known as Shawano, on the Hillsboro Canal about 12 miles below the Station, down in the heart of the Everglades. It was at this same time, too, that Mr. George E. Tedder, who had been Foreman of the Everglades Station since December 10, 1923, made the flat offer of $5.00 per bean (**) for every bean ever to be grown on "saw-grass land," so often had he seen planting after planting of all kinds of crops come up hopefully only to wither and perish without exception. Snap beans were of course understood.

Before briefly discussing the results of those early tests at the Experiment Station and the numerous others that have followed, it is regrettable to report that, due to the absence of treatment with copper in any form, not a single, mature peanut was developed on the entire 1,000 acres down at Shawano that had required many tons of seed for the planting. It is likewise regrettable that Mr. Tedder's earthly estate must needs find itself so wholly inadequate to meet the gigantic responsibility which he flung against it with such well-meaning abandon that Spring morning in 1927 in view of the developments that have followed. For if George were really to assume that responsibility and "Pay up," the National Debt quite readily could be wiped out with a single Postal Order from Belle Glade and, additionally, without cutting into the main body of the accumulated and accumulating revenues too greatly, enough moneys set aside to refurbish the whole earth against the enormous physical damage done by the most recent world war. In other words the good peat soil of the Everglades has produced many a bean since that time and is still producing them by the tens of thousands of hampers each year, due first to copper and second to manganese, insofar as the trace element relationships that have been developed are concerned. Zinc and boron have shown almost equal

—Vice Director in Charge, Everglades Experiment Station, University of Florida, Belle Glade.

—In the presence of Mr. J. H. Hunter, Asst. Agronomist at that time, and the writer, then Soil Specialist.

indispensability for other crops under certain conditions so that these four elements have indeed proven themselves the "Four Horsemen" of Everglades agriculture, the developing need for phosphate and potash with the progress of cultivation and cropping out of the soil being taken for granted, of course.

The initial set of trace element treatments referred to above involved a dozen chemicals and other materials including copper, manganese, and zinc, all in the sulfate form at different rates per acre. These treated plots were laid out in duplicate on freshly-cleared, very raw, sawgrass peat as long, narrow areas in such a way that a wide variety of agricultural plants could be planted across all of them as continuous rows interrupted only by narrow alleys running lengthwise between the plots. The nature of the sawgrass cover in those early days is well shown in Figure 1.

The Primary Plant Response

Inasmuch as these first plant responses to copper, manganese and zinc were outlined in some detail in Bulletin 190 (1927) of the Florida Experiment Station and have been referred to quite frequently since that time they now will be passed over quickly, the response taken for granted, as it were. However, since the above bulletin has been out of print for many years, a few of the photographs on a small scale will be included at this time especially to show the wide range of agricultural plants definitely requiring these trace elements for normal growth under the native conditions that prevail in this organic soil which is now officially known as Everglades peat. Particular reference is, of course, to copper in the raw, unburned, peat. The photographs of Figs. 2-8 with their brief legends appended really tell the story much better than words regarding these responses of all field and truck crops to these elements.

An unusual copper deficiency pattern is shown in Fig. 9 on the leaves of the sugar cane variety Coimbatore (Co.) 281. This frequently was mistaken for mosaic in the early days when the occurrence of such deficiencies in this and other farm crops of the area were the rule, rather than the exception, as at present.

Unusual responses likewise were obtained in those early days from a number of different materials. Mention already has been made of compost. Caustic lime also should be included. Then too, there was observed an extremely interesting plant response to treatment of the raw soil with creosote. The reaction of sugar cane to this material is shown in Figures 10 and 11. Further interesting observations as to the nature of these essential growth factors were made by layering canes from parent stools, where the soil had been well treated with copper and other necessary elements, down into raw soil that had received no treatment whatsoever. The extraordinary response to such a continuing contact with the parent stool is shown under greenhouse conditions in Figure 12 and under field conditions a little later in Figures 13 and 14.

The same type of complete responses also were obtained thru the use of copper on tree crops, as are well shown in those appearing in Figures 15-18.

MANGANESE

While copper in one form or another has proven completely indispensable, even though it be present only as traces in compost or other crude chemical compounds, it was soon found that where the soil pH is near or above neutral (7.0) manganese becomes unavailable for a wide variety of plants as shown in Figures 19-22. When this condition occurs response is obtained by several means but notably by soil treatments with manganese or with sulfur or by dusting or spraying the element directly onto the foliage of the plant in one form or another.

Here again tree crops, such as palms, suffer the same as smaller plants when the availability of manganese becomes too much depressed by excessive lime in the soil. The four Figures 23-26 showing several different varieties of palm trees in the Palm Beach area are illustrative of this condition. These were some of the first treatments with manganese in this area. While these trees were on highly calcareous mineral soils, the response of these palms on high-lime organic soils is essentially the same. All survived as a result of manganese treatment in some form although all were near death at the time of treatment. These early studies have been followed up very energetically through the years, first, by Mr. John R. Wilson, and later by others, with excellent success on a commercial scale. It was at about this same time that the first response of citrus to manganese was obtained on a high lime section of the "Home Grove" of Mr. Walsh at Davie, where in his ridging operation he had practically capped his planting ridge with marl brought up from beneath the comparatively shallow layer of peat at the south end of his planting. These results were reviewed at the 1931 meeting of the State Horticultural Society and published in the Proceedings of the Society for that year.

COMBINATION TREATMENTS

As might be expected, where a particular soil environment contains deficiencies of more than one element, nothing like normal growth in a plant requiring both could be expected from the use of either alone. This relationship became very obvious in the very first trials referred to above where the peanut plant was involved and under conditions of copper application to the soil (30 pounds per acre of bluestone in the row) immediately prior to the planting of the seed. The seeds on all treatments germinated promptly and came up uniformly but stopped growing on all plots after ten or twelve days, including those on the copper treatment. They then assumed either a low dense rosetted

form in the top with leaves yollowing and spotted, as shown in Figure 27, or grew up a few inches in tiny spindling plants. This was not true of the plants on the zinc treatment since they continued growth right on thru this early period but it was of a more erect, spindling type though they never grow to more than 6 to 8 inches in height. This delay in the early copper response and prominent activity of the zinc response thru the early period of growth naturally raised the question of prospective benefit from a combination treatment. It was largely on account of this strikingly differential response that the first, more detailed study to follow the very first treatments was with peanuts on fair sized plots with individual and all possible combination treatments of copper, manganese, zinc, caustic lime and stable manure, all five materials having given various degrees of response on different plants when used individually in the first tests.

Reference will be made in these studies only to the copper-zinc response since it was so outstanding and so well demonstrated the point under test and discussion. Again, the plants on the copper treated plots came up to a good stand and, for the first five or six weeks looked very much like the plants on the untreated (check) plots. On the other hand, each of the uncoppered plots that received zinc again exhibited the same continuity of early growth observed before, but only of a spindling, abnormal type that eventually came to naught. In the instance of the combined treatment with copper and zinc, however, there was no delay whatsoever in the normal growth of every peanut plant on each plot receiving simultaneous treatment with both elements. Regardless of whatever other components any of the treatments contained, the copper-zinc combination was outstanding in the promptness, continuity and completeness of its response as is evident in Figure 28 where the plants from the dual treatment matured 5-6 weeks ahead of those receiving only the copper treatment. This response was well emphasized by the yield data which grew out of these plots. While no yield whatsoever was obtained from uncoppered plots, good yields and an early harvest came from the plots receiving the copper-zinc combination and a good yield but delayed harvest from those receiving only copper sulfate. A closeup view of some of these plots is shown in Figure 29 while Figure 30 shows, above, a general view of the experimental setup before the storm of September 1928, and, below about a fortnight following it.

These reactions were discussed before the Plant Physiology Section of the American Association for the Advancement of Science in December, 1928 in New York but the paper was not published at that time.

In subsequent studies on these same plots, after converting to general fertility work due to scattering of trace element treatments by the storm, and including adequate amounts of phosphorus and potash, along with supplemental trace element

treatments, yields up to 3000 pounds of peanuts (Little Spanish) per acre were obtained along with the same amount of tops as hay. In these later studies the rapid cropping out of first potash and then phosphate was clearly demonstrated. In fact responses to either of these two major elements became almost as dramatic as those to copper or any of the trace elements that are reviewed above when the element was restored after the soil had been cropped to a very low level. The helplessness of copper in the absence of adequate supplies of the major elements is well shown in the results of some of the early greenhouse studies presented in Figure 31.

Insofar as greenhouse work with the trace elements is concerned, much better results were obtained when improved sources of distilled water were to be had. This is understandable when it was found in the course of later work that passing ordinary tapwater thru a conventional still increased its copper content ten times. Redistilling thru quartz or passage thru absorbing resins have given good protection in work of this type as exemplified by the excellent results reported by Dr. W. T. Forsee, Jr., in Volume II, Soil Science Society of Florida and elsewhere.

Residual Values in the Soil

One of the earliest checks following the first cropping of the individual application of copper in the first series of treatments was on the localization of that 30 pound treatment that had been placed in the row and of the residual values that remained. This was first done with the common beggarweed by opening up the original line of planting with a small hand plow after first preparing light planting furrows between the rows, the plow being carefully cleaned between each such operation in any event. Both sets of rows were simultaneously seeded to beggarweed with the results that are shown in Figures 32 and 33.

It was obvious from the plant response that there was sufficient copper remaining from the earlier treatment to adequately supply the additional planting since the plants made just as luxuriant growth as before. However, those plants between the rows and out of immediate contact with the residual copper failed completely even though they were in a soil filled with healthy, vigorous roots of plants growing 18 inches away but with a local contact with the copper already in the soil as residual from the earlier treatment. This tremendous permeation of the soil by plant roots is well shown by the block of rape roots excavated from the row to half way across the middle to the next one. This is shown in Fig. 34.

Naturally where response of plant growth is so unusual to such small amounts of chemical, great care must be taken in all field operations to avoid contamination. That is why the great storm and flood of 1928 had a particularly disrrupting effect on the work of the Experiment Station at that time.

Rate of Treatment

Although we now know that organic soils and the organic components of mineral soils have a very great absorptive power for such metallic elements as copper, the upper and lower limits of treatment with such materials was deemed worthy of investigation in the early days of these responses. Thus by graded applications in box plots of about 1/2000 acre in size it was found that bean plants would tolerate quite well applications of copper sulfate or manganese sulfate up to 10,000 pounds per acre as well as zinc sulfate in similarly high amounts if well mixed with the topsoil and allowed to stand a few days before planting. In addition to the "buffering" effect of the organic matter in the soil it must be remembered that our typical Everglades peat is directly underlain with lime rock and the soil has a high calcium content in consequence thereof. This, of course, adds very substantially to the absorbing or retaining power of this soil for elements such as copper, manganese, zinc ,and boron which are found to leach only very slightly from it—even less, apparently, than phosphorus and potassium. Their actual availability for the use of plants under such conditions, is, of course, another question that depends very much on the reaction (pH) of the immediate soil environment as well as the ability of the individual plants (their "Feeding Power" as Dr. Truog has so well called it) to absorb their requirements from the form in which such elements are to be found in the soil.

Soil Testing

In view of the mounting cost of fertilizer materials and the maintenance of a normal fertility level in the soil, the need for as much help as possible from soil and tissue testing in determining optimum applications becomes even greater with the advent of a whole series of trace elements into our soil fertility picture since, almost without exception, they are much more expensive than the so-called major elements.

Companion information in this same field of which we also have so little and need so much, is the composition of the plant material itself not alone in terms of what it takes to make a maximum growth or weight yield but also in terms of what composition individual plant materials should have in terms of these several elements to be of maximum value as a feed for animals and as food for man. This should well give a second basis for the future calibration of testing methods, both soil and tissue, if they are to be of maximum assistance.

Since we have come to recognize so fully the very great importance of many of the so-called trace elements to the health and growth, alike, of plants, animals and man during the past quarter of a century it would seem the service of future research in this field to the cause of plant, animal and human health would

be much greater if it were set up in such a way as not only to enlarge our understanding of the importance and function of each element but also arranged, and extended if need be, to include ways and means of routine soil and tissue testing to develop a system of protective information, of an Extension nature if you please, against the tragic losses that can follow the use of too much as well as too little of any or all of these secondary elements in a particular situation.

Figure 1.—The native sawgrass (Cladium sp.) from which the great mass of Everglades peat was largely formed. Jimmie Seal, Jr. in photo taken out in the Southeast Section of the Everglades Experiment Station on Feb. 12, 1928.

Figure 2.—Sugar Cane, U.S. 663
Left—Check (no treatment)
Right—Copper sulfate 30 lbs. A.

Figuie 3.—Left—Check (no treatment and no plants)
Right—Copper sulfate 30 lbs. A.
Reaı—Crotalaria retusa
Middle—Crotalaria juncea
Front—Clitoria ternata

Figure 4.—Red beets
1. Copper sulfate
2. Manganese sulfate
3. Compost
4. Check (no treatment and no plants)

Figure 5.—Rape
1. Copper sulfate
2. Compost
3. Manganese sulfate
4. Check (no treatment)

Figure 6.—Another view of the remarkable response in sugar cane (Variety U.S.1639, left and U.S. 1637, right) to treatment of raw, Everglades peat with copper:

Below: general soil treatment with phosphate and potash but no copper, the plants on the copper-treated plots (closeup above) showing over the back-stop.

Above: same varieties of cane and same general soil treatment but with copper in addition. These two rows ran across five different soil treatments, including, of course, the check. These photographs taken about two and one half months before the great storm of September 16, 1928.

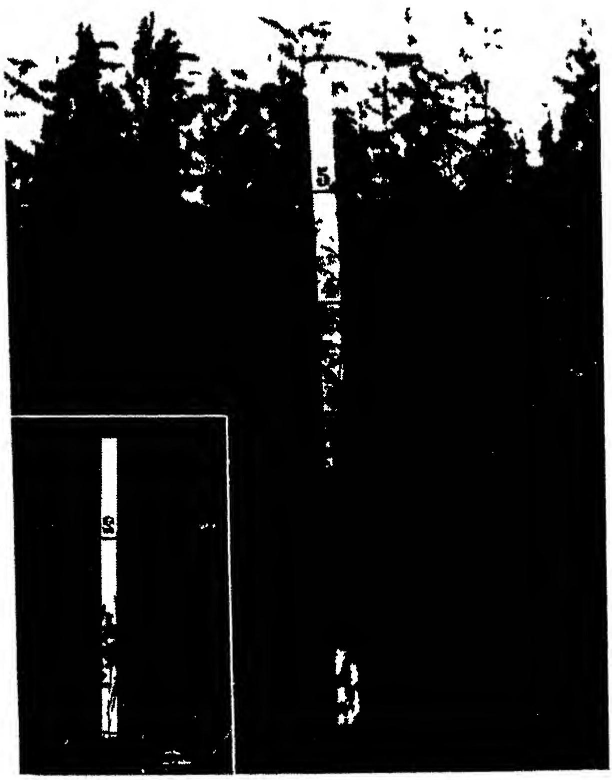

Figure 7—Response of sesbania, one of South Florida's most popular and useful leguminous cover crops, to treatment of freshly broken Everglades peat with 30 pounds of copper sulfate per acre in the row. Inset shows plants of the same age on check plot that had received no copper. Photo taken 80 days after planting.

Figure 8.—Pangola grass on raw sawgrass soil showing early stages of response. Plot in foreground received no copper and plants growing largely on the cuttings died out later. Plot immediately to rear received copper. Growth started strong and continued so.

Figure 9.—The appearance of copper deficiency on the foliage of sugar cane variety Coimbatore (Co.) 281, having much similarily to a mosaic pattern.

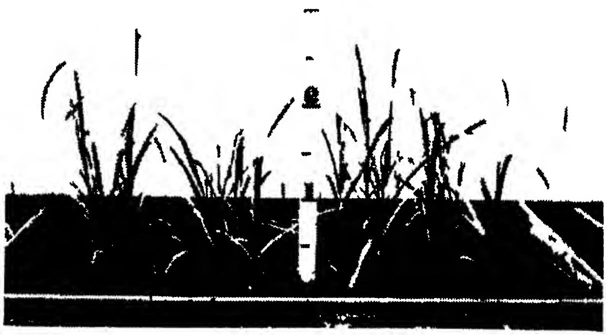

Figure 10 —Sugar cane, variety Co 281 on freshly broken sawgrass land, Check (untreated)

Figure 11 —Same as Figure 10 but the raw, peat soil given a light treatment with creosote and worked into the top six inches

Figure 12.—The effect on growth of Co 281 sugar cane in Everglades peat of continuous contact with a parent stool growing in soil fully treated with copper under greenhouse conditions.
Right—Parent stool.
Center—Cane from stem "layered" in uncoppered soil.
Left—Cut cane planted in uncoppered soil.

Figure 13.—Cane varieties from cut seed pieces in soil treated with Cu-P-K just prior to planting.
Left—D-117.
Center—Crystalina.
Right—Co 281.

Figure 14.—Same general soil treatment as in Figure 9 but with Co. 281 stems layered into the soil from which very superior growth is developing.

Figure 15.—Duncan grapefruit on sour orange stock at about one year of age (Everglades Peat):
Left—Check (no treatment)
Right—Copper sulfate

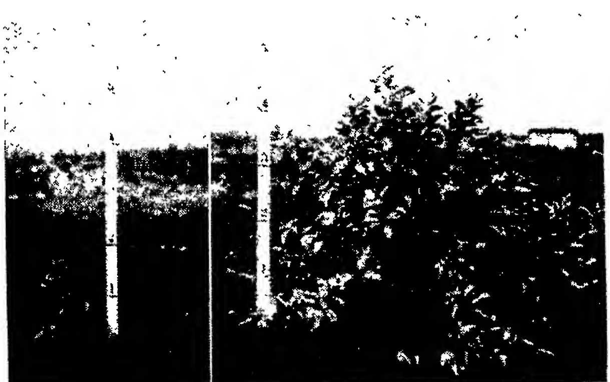

Figure 16.—Villa Franca lemon on sour orange stock at about 17 months of age (Everglades Peat):
Left—Check (no treatment)
Right—Copper sulfate.

Figure 17.—Collinson avocado (Everglades Peat):
Left—Check—at about 1 yr. of age.
Middle—Copper sulfate at 1 yr.
Right—Copper sulfate at 28 mo.
Note: Check plants all dead at time of this later photo.

Figure 18.—Jewel Peach at about 16 months:
Left—Check (no treatment)
Right—Copper sulfate
(Everglades Peat)

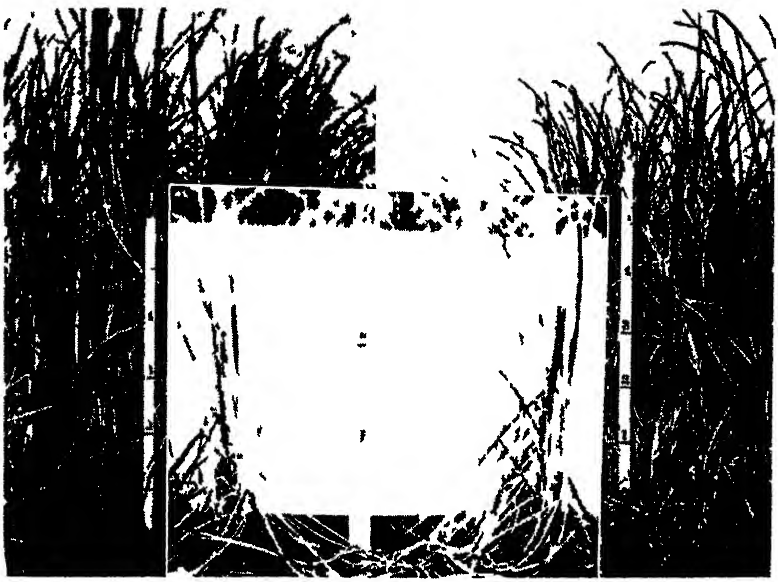

Figure 19.—Response of sugar cane, Variety Co. 281, to treatment of badly burned Everglades peat with sulfuric acid or with acid-producing sulfur to release manganese to the plant. Parker area near Moore Haven.

Left: Sulfur Center: Check Right Sulfuric Acid

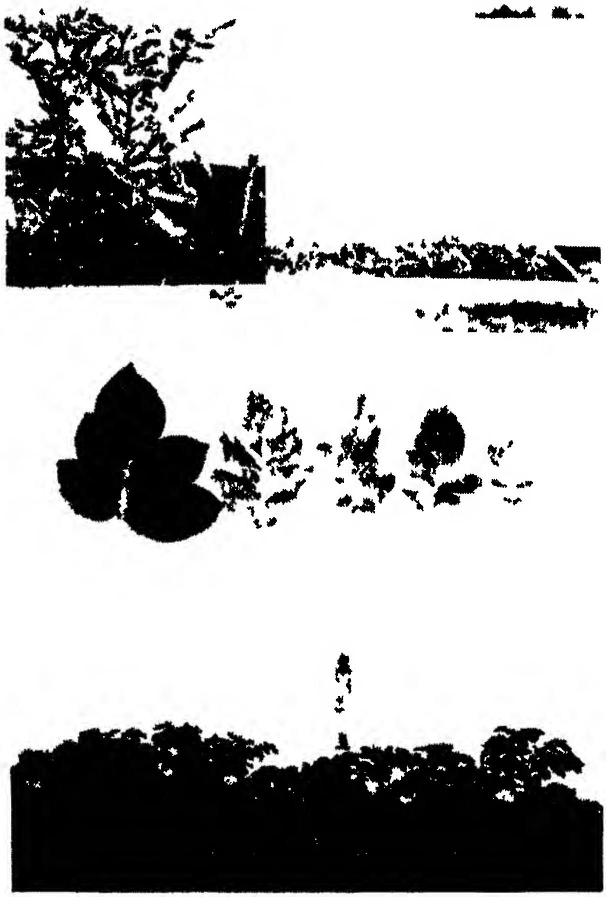

Figure 20.—Response of the Irish potato to treatment of badly burned peat soil. Top: Check plot and closeup of single plant. Center: Injured foliage series from left—normal, to right—colorless and nearly dead. Bottom: Normal growth of potatoes where fertilizer treatment included a generous quantity of manganese.

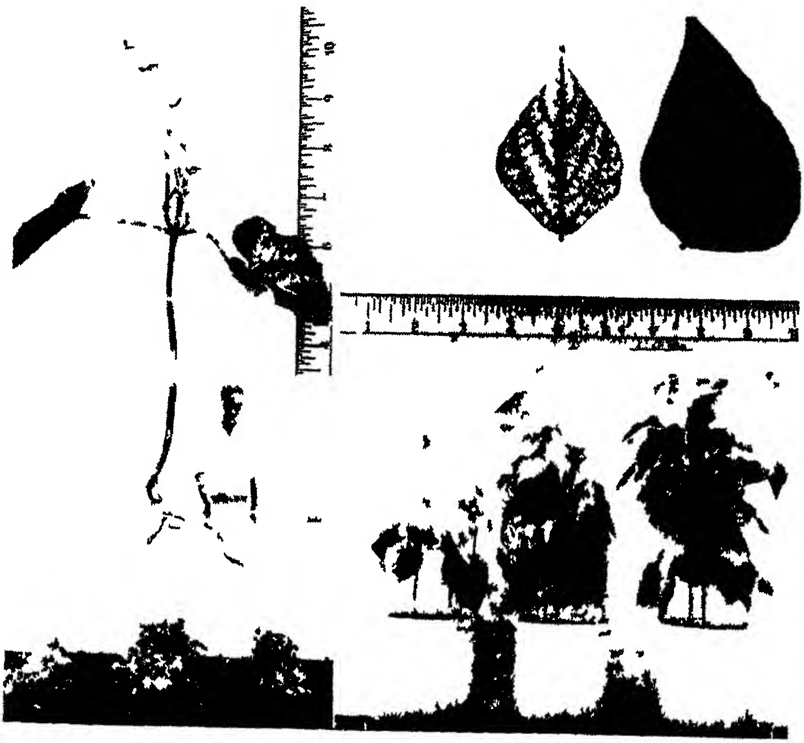

Figure 21—Upper left A typically chloratic bean plant due to manganese deficiency Upper right Bean foliage series showing range of manganese deficiency effect Right—normal, Center—badly affected, Left—extremely chloratic and dying Lower left Response of beans to treatment of soil with high pH (Maloy area, Dr J L Seal in photo) Left—check untreated, Center—Copper, sulfur P O and K_2O, Right—sulfur only Lower right Beans on "beansick" Pahokee soil Left—check, untreated, Center—Superphosphate, Right—Manganese and superphosphate

Figure 22—Response of radishes to treatment of burned soil Left Check, no treatment, no plants Right Treatment with manganese and sulfuric acid H H Wedgworth, Plant Pathologist at Everglades Experiment Station at that time, in photo (Feb 26, 1931)

Figure 23 —Cocos plumosus palms in high lime soil along S Third Street in Palm Beach failing because of the unavailability of manganese under such conditions of high pH Center is a closeup of a palm typical of those found on either side of the street, left and right

Figure 24.—Closeup of Cocos plumosus palms on one of the large estate plantings in Palm Beach where failure is also due to the high lime content in the soil

Figure 25.—Royal palm failing badly, left, in the municipal area of Palm Beach where it had been planted in a soil containing too much free lime; also, right, on one of the larger estates where one of the "key figures" in its landscape architecture was dying for want of manganese at the time of the photo.

Figure 26.—"Fishtail" palm, growing quite close to the Cocos plumosus of Figure 24 and under essentially the same soil condition, is failing for the same reasons—unavailability of manganese under such high lime conditions in the soil.

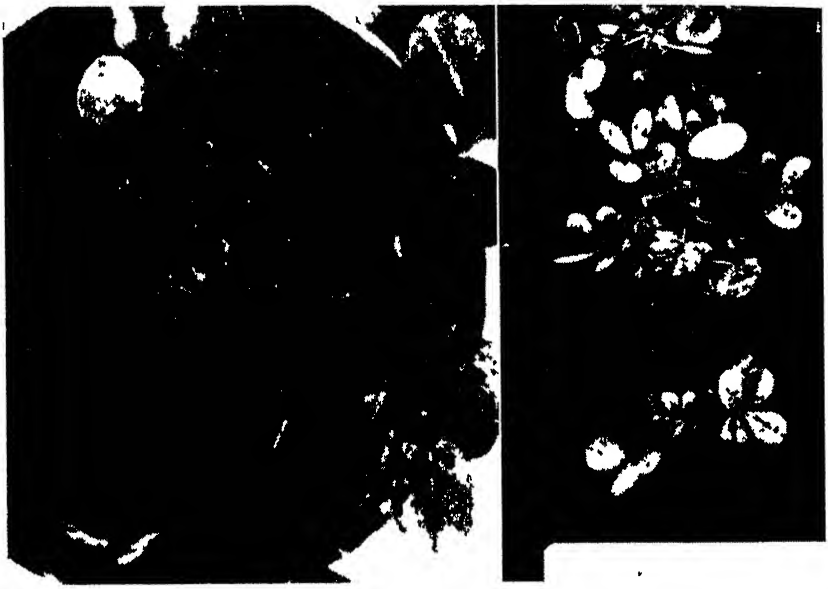

Figure 27.—Little Spanish peanuts growing on untreated Everglades peat showing extreme rosetting in all plants with foliage off color, leaves badly spotted and central growth in most of them nearly dead.

Figure 28.—Response of Little Spanish peanut plants to soil treatment with copper and with a combination of zinc and copper (sulfates). Left: check, no treatment; Center: Cu-Zn combination, the defoliation being due to normal ("early") maturity; Right: copper only, heavy with foliage due to late start and late maturity.

Figure 29.—Closeup view of the peanut plots involved in the copper-zinc response: Foıeground, left—copper, zinc, caustic lime and manure. Center —manganese, zinc, caustic lime and manuıe. Right—copper, manganese, zinc, caustic lime and manuıe. Background, center— check, no treatment. Note: the mulch covering (sawgrass straw) on half of each plot represents another phase of the study—an effort at lowering the soil temperature at the surface.

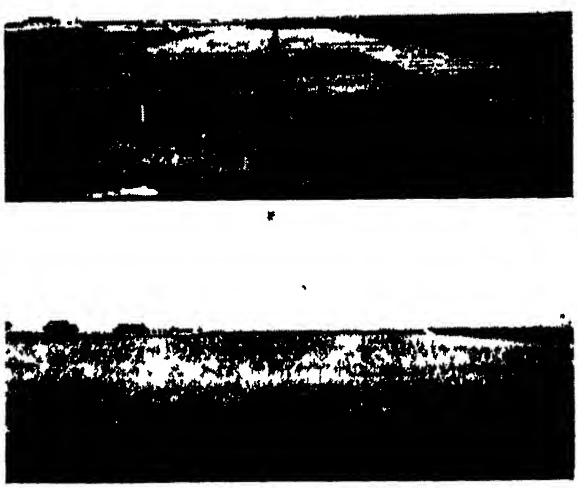

Figure 30.—General view, before (above) and after (below) the storm of 1928, of the series of peanut plots receiving single and all possible combinations of five different materials—copper, manganese, zinc (all as sulfates), caustic lime and manure. Photo taken from essentially the same position in both instances, i.e. on what was then the South Dike of the Experiment Station. Note that in the latter photo only the tops of the stakes along the central alley are showing though photo was not taken until about two weeks after the storm.

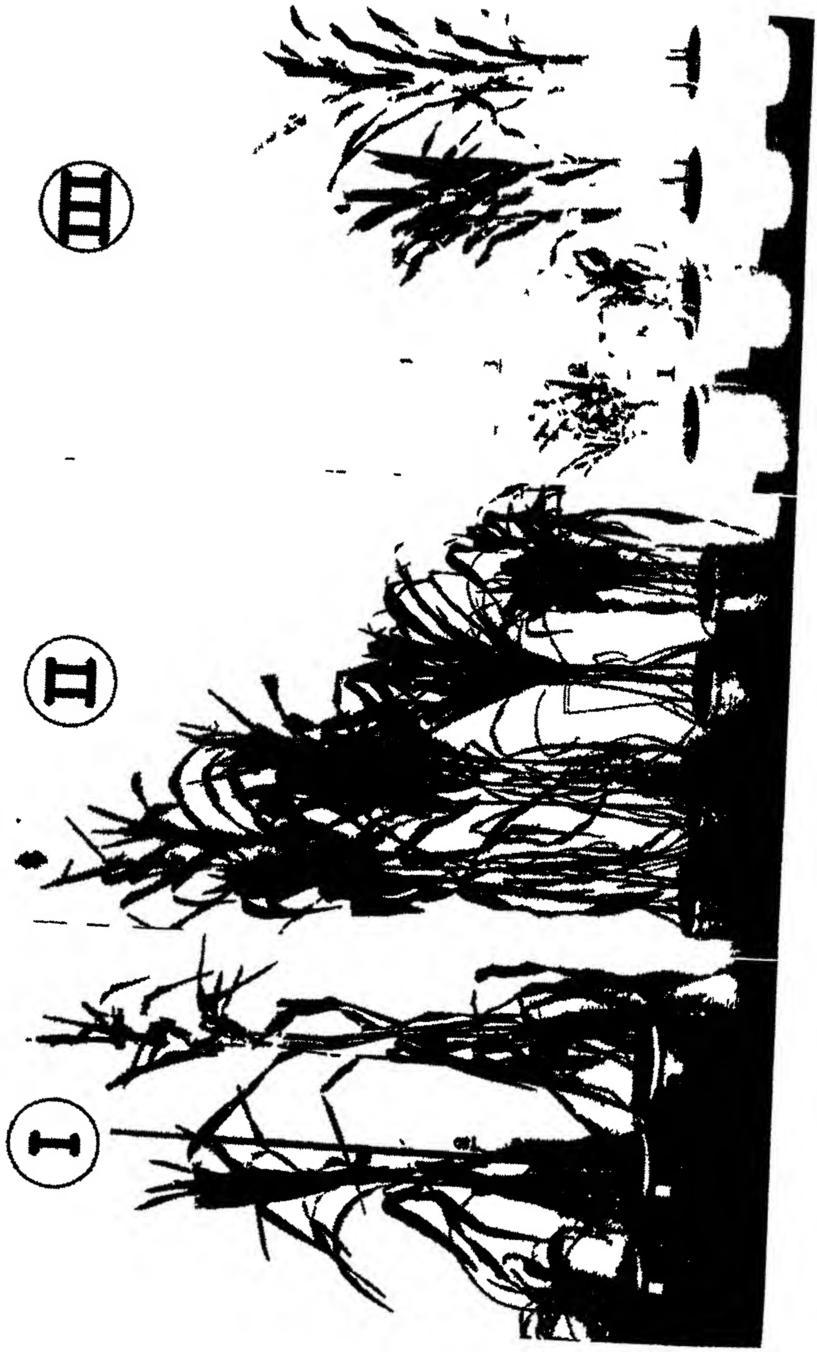
I
II
III

Figure 31.—Limitation of corn growth by cropping out of major element supply as shown by several early series of greenhouse studies:

I. Left, copper sulfate and superphosphate.
Center, copper and potash.
Right, copper, potash *and* superphosphate.

II. Right, check, no treatment.
Right center, copper sulfate.
Left center, copper and potash.
Left, copper, potash and superphosphate.

III. Left, check, no treatment.
Left center, copper sulfate.
Right center, copper and potash.
Right, copper, potash and superphosphate.

Figure 32.—Beggar weed plants failing on the check plot of the trace element series where three of the original planting rows were replanted and a row seeded in each of the middles to conform with the planting on the plot that received the earlier copper treatment, Figure 33, below.

Figure 33.—Beggarweed in second planting on copper treated plot to show residual values. Three rows with good growth are in the original lines of treatment with copper sulfate while the two rows that are failing completely have been planted entirely out of contact with this copper. These little plants are dying for lack of copper though the soil in which they are trying to grow is completely filled with strong healthy roots (see rape roots of Figure 34) from the plants adjacent which have access to the copper that is residual from the earlier treatment.

Figure 34.—Block of soil containing rape roots as excavated from one of the copper treated plots from the row (looking down into plant stubble) to somewhat more than half way across the middle to the row adjacent. This is to show the complete manner in which the roots of healthy, copper-treated plants completely permeate the soil when growing as normally as the beggar weed plants of Figure 33.

RESPONSES OF PASTURE AND FIELD CROPS TO TRACE ELEMENTS ON *MINERAL* SOILS IN FLORIDA

ROGER W. BLEDSOE*

Visual deficiency symptoms have been used primarily as a guide to the adequacy of trace elements in the nutrition of pasture and field crops grown on the mineral soils of Florida. Such symptoms may develop only when the deficiency is severe. Chemical analysis of soil and plant may be of value in determining the cause when plants show deficiency symptoms. However, if the plant shows no deficiency symptoms such analysis may be of questionable practical value in determining whether an element is limiting in the nutrition of the plant. Soil analyses do not show the availability of the trace elements. The concentration of an element within the plant may not serve as an index of deficiency because deviation from the normal might occur only when the deficiency is extreme. Furthermore, with most pasture and feed crops the concentrations of trace elements required within the plants have not been established.

PASTURE PLANTS

Results by Killinger, et al., (11), indicated trace elements to be beneficial in the establishment of Dallis, carpet, Bermuda, and Bahia grasses on certain virgin flatwoods soils only when used with lime and a complete mineral fertilizer. Copper appeared to give the greatest growth response followed by manganese, zinc, and boron in decreasing order. The trace elements did not have any significant influence on yields after the grasses were established.

Hodges, et al., (8-9), reported similar results with grasses. A combination of three elements, copper, manganese and zinc, gave yields superior to those where only one element was applied. Common Bermuda did not respond to applications of trace elements while the response by common Bahia was less than that of carpet and Pangola grasses. The growth and survival of Pangola grass was distinctly improved when only copper was applied. A rate of 5 pounds per acre of copper sulphate was as beneficial, in some cases, as higher rates.

Boron has been shown frequently to improve seed setting of clovers when grown on the mineral soils. Killinger, et. al., (11), observed boron deficiency symptoms of California burclover when grown in the absence of boron fertilization. Seed setting of Black medic and Annual sweet clover was greatly improved when boron was applied (14). Clovers have not re-

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sponded appreciably to applications of other trace elements with the possible exception of zinc (3).

Hodges, et al., (10), reported the growth of common and Kobe lespedezas was considerably improved when fertilized with copper, zinc, manganese, and borax as compared to the no-trace element treatments. However, trials with other legumes showed no response to trace elements.

The importance of trace elements can not be minimized where needed for the growth of pasture plants on mineral soils. Crop failure may result on those soils naturally deficient in one or more of the trace elements as well as on alkaline or overlimed soils, unless the needed elements are added regardless of the quantities of nitrogen, phosphorus, and potassium applied. Where needed for pasture plants the following rates per acre are generally recommended: 15 pounds each of copper and manganese sulfates, 15 pounds of zinc sulfate, and 10 pounds of borax.

Field Crops

In 1935 Barnette and Warner (2) described the visual symptoms of white bud of corn and demonstrated it was due to a deficiency of available zinc in the soil. In 1936 Barnette, et al., (1) described zinc deficiency symptoms of velvet beans, cowpeas, and millet. Oats grown on land which had produced white bud of corn responded favorably to the application of zinc sulphate with increased yields, while peanut yields in some cases were increased but symptoms of malnutrition were not observed with either crop. Yields of sugar cane, Napier grass and crotolaria were likewise increased by the application of zinc sulphate but deficiency symptoms were not observed. Thus, the value of zinc for preventing the development of plant disorders and for increasing plant growth was established.

Results by Barnette et al., (1) showed that "resting the land" or permitting it to lie fallow to volunteer weeds and grasses had reduced materially the percentage of white bud corn plants of experimental plots. The incorporation of a relatively heavy planted crop of crotolaria had not been as effective as that of native cover crops in reducing white bud of corn. On plots planted to corn and peanuts annually the corn showed by far the largest percentage of white bud.

Results by Rogers, Gall and Barnette (13) show that the dry matter of weeds collected from plots "rested" for 2 years averaged 140 p.p.m. of zinc; that of *Crotolaria spectabilis* Roth. planted annually 8 p.p.m. The dry matter of weeds and grasses collected from plots "rested" for 1 year averaged 70 p.p.m. of zinc, that of 3 species of crotolaria planted in plots in a 2-year rotation with corn and peanuts 21 p.p.m. The authors state that the data indicate weeds and volunteer grasses are able to absorb much larger proportions of zinc than are planted land covers

and apparently make available sufficient zinc to prevent the development of white bud of corn.

The author has observed white bud of corn grown on mineral soils in various areas of the state. Some varieties of corn, for example, Dixie 18, appear to be more sensitive to available zinc supply than other varieties. The occurrence of white bud appears also to be closely associated with climatic conditions. Some seasons the disturbance is far more prevalent than that of other years in the same region. However, in many instances the young plants seem to recover rather rapidly, even without the addition of zinc, and the yield of corn is thought to be little affected.

Nutritional disturbances attributable to zinc deficiency, other than that of corn, are rarely noted in field crops grown on mineral soils. However, specific deficiency symptoms of value for diagnostic purposes have not been established for many of the field crops. When plants are grown under field conditions the symptoms may be difficult to recognize, not visible, or masked by other plant ailments. Zinc deficiency symptoms of peanut have not been observed on field grown plants, while symptoms are very distinct when plants are grown under controlled conditions.

The author demonstrated zinc deficiency of peanut when plants were grown under controlled conditions and supplied repurified chemicals and redistilled water. Symptoms of zinc deficiency were evident within 14 days on the Holland Station Runner Jumbo variety and 21 days with Dixie Runner variety after zinc was withheld from roots of plants. The first evidence of a disturbance was retarded growth and reddish coloration of stems and petioles. The leaf pattern might be described briefly as "little leaf" which is especially evident in the terminal growth where it appears first. The foliage is small, narrow, crinkled, and chlorotic at tips. Midrib and major veins of older leaves have a prominent light color. The blades are thick and leathery and wrinkled along the midrib. In advanced stages the midrib breaks down and necrotic areas appear irregularly over the leaflet's surface. The pattern progresses from terminal to basal portion of plants with age.

Distinctive symptoms of copper deficiency in field grown plants on mineral soils have been reported in only a few cases. However, because of the low content in soils of some areas copper is often suspected of being the trace element most likely to be a limiting factor in plant growth.

Hodges et al., (10) reported that oats grown on Portsmouth fine sand, mucky phase, developed mineral deficiency symptoms which were completely remedied by the application of 15 pounds of copper sulfate per acre. There was no evidence of copper deficiency in oat plants grown on the adjoining prairie phase of Portsmouth fine sand.

Harris (4) described a nutritional disturbance in oats grown on Arredonda loamy fine sand at Gainesville which could be

cured only by additions of copper salts. A very small amount of copper chloride (2 pounds per acre) was beneficial and had considerable residual effect (5). High applications of nitrogen accentuated the abnormality and caused a decrease in grain yields. The yield of shelled corn was increased 20-23 per cent in consecutive years when copper chloride was applied at 10 pounds per acre even though symptoms of a deficiency were not evident. Yields of barley, wheat, and cowpeas were increased also by applications of copper while the yield of rye was not affected. (6)

Harris (7) describes a nutritional disorder of peanuts, when grown on the same location as that of crops mentioned above, and demonstrated its control by the use of copper salts. Exceptionally small amounts of copper chloride applied as a spray had a pronounced influence on yields. Affected plants had small, irregular terminal leaflets with small yellowish-white spots, marginal necrosis and some interveinal chlorosis.

Copper deficiency symptoms of peanuts grown in nutrient solutions in the greenhouse, as demonstrated by the author, were somewhat different from those described in field grown plants. Thirty days after copper was withheld from the roots the young leaves of some plants withered suddenly without any other symptoms. Terminal leaves were small and interveinal chlorosis occurred on the leaflets of the second or third leaf below the growing tip of some plants. Stem tips ceased to grow but stems were not discolored. In the more advanced stages the young growth withered and died on all plants.

In a field test the author observed a nutritional disturbance, similar to that reported by Harris (4), in young peanut plants of three of six replicated plots. Copper-sulfur dust was applied to all plots. The disorder was corrected and there was no sigficant difference in yields. Yields of peanuts grown near Live Oak were increased by approximately 30 per cent by applications of copper-sulfur dust. Treatment of other trace and major elements had little influence on yields (unpublished data by the author and Mr. Fred Clark). Results by Killinger, et al., (12) and unpublished data accumulated by Station workers during the past several years show that yields of peanuts dusted with copper-sulfur are usually superior to those dusted with sulfur. It is suspected that the added response to copper-sulfur dust is in part nutritional.

Severe symptoms of manganese deficiency are rarely observed in farm crops grown on the mineral soils. Perhaps that is because a majority of the soils used in the production of farm crops are acid in reaction while manganese deficiency is usually associated with soils of a neutral or alkaline reaction. Under some circumstances, slight deficiency symptoms may appear, especially during prolonged periods of dry weather and then disappear after heavy rains. However, it is frequently difficult to distinguish between manganese and iron deficiencies, since

in both cases the veins are green. Manganese deficiency symptoms are sometimes observed in over-limed areas.

The author demonstrated manganese deficiency symptoms of the peanut when plants were grown in nutrient solutions. The deficiency appears first as interveinal chlorosis in tip leaves and then moves progressively toward leaves at base of plant. Chlorosis starts frequently at the base of a blade and progresses toward leaflet tip. The green color of veins is not prominent. Later the entire leaflet turns yellow and necrotic spots appear irregularly over the surface but rarely at leaflet margins until late stages. Large areas of leaflets then turn brown and leaves drop prematurely.

Chlorosis due to iron deficiency is frequently observed in lawn grasses, especially in centipede and St. Augustine. It is rarely observed in other crops grown under field conditions.

Responses to application of molybdenum to field crops grown on mineral soils have not been reported. The author observed evidences of molybdenum deficiency of peanuts during two consecutive years when plants were grown on plots at Marianna to which no molybdenum had been applied. The leaves of untreated plants were yellowish to pale green as compared to the dark green leaves of treated plants. The symptoms occurred during the early growth stages and later disappeared. Yields of those plots were not significantly lower than those of plots to which molybdenum had been applied. Florida Station workers have observed similar symptoms in peanuts, cowpeas, and crimson clover during early growth stages which later disappeared. Yield responses were not obtained where molybdenum had been applied.

Symptoms attributed to boron deficiencies of crops grown under field conditions have not been reported. However, flue-cured tobacco fertilizers usually contain approximately 2.5 pounds of borax per ton of fertilizer.

In general the mineral soils used in the production of pastures and field crops are very sandy, very low in organic matter, and have a low level of fertility. Mineral fertilizers, where used, are applied at low rates. Sprays and dusts which might contain some trace element are rarely applied to pastures and field crops. The practice of allowing land to lie fallow to volunteer natural cover crops is decreasing rapidly. Planted cover crops are being used more extensively. It would appear that on such areas any intensive farming practices which would be a soil depleting program could soon lead to difficulties. If climatic factors, soil moisture, and major elements supply, which are frequently the limiting factors in field crop production, are particularly favorable for plant growth it is quite possible that many of the otherwise adequate soils could become deficient as a source of trace elements necessary for maximum yield production.

During some seasons deficiency symptoms of trace elements

are more prevalent than those of other years. Deficiencies are often manifested at early stages of plant growth, or during periods of dry weather, and then later disappear. Stunted growth attributed to other plant ailments is often thought to be associated with trace element deficiencies. Results of studies to date indicate that with the exception of a few areas there is no critical shortage of trace elements in the mineral soils of the state. However, they also indicate that at times the availability of trace elements may be below the optimum physiological requirement necessary for maximum growth and yield of plants. In such areas the producer of crops and livestock must be aware of the importance of the trace elements, for to him, it could mean the difference between success and failure.

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TRACE ELEMENT RELATIONSHIPS IN FLORIDA VEGETABLE CROPS ON *MINERAL* SOILS

J. R. BECKENBACH[1]

INTRODUCTION

Much of Florida's vegetable crop production—especially the fruit crops such as tomatoes, peppers, eggplant, squash, etc.—is located on relatively flat sandy soils of the poorly drained sands. Water control, both drainage and irrigation, are essential to production on such soils. Vast areas of mineral soils are under such control in the important areas of the state.

Some of these areas are natively good to high in soil reaction; the marl soils of the Homestead area having a pH in the range of 8.0 and a bit higher, and Parkwood and related soils ranging from pH 5.5 on up to slightly above 7.0. Other soils utilized extensively are natively very acid, however, Leon sands, for example, natively range from pH 3.9 to 4.4.

All have been heavily leached over the centuries, and those of low pH are very low in soluble salts, including both major and trace element bases. When these are limed and fertilized for vegetable crop production, this lack of trace element bases becomes apparent. For this reason, the magnesium carrying dolomitic limestone has proven better than high calcic lime, and basic slag has usually proven superior to both. The manganese content of the slag is of unquestioned importance in making these comparisons.

Magnesium, manganese, iron, zinc, copper and boron have all been found to be deficient in certain of these limed soils. On an emergency basis, deficiencies of all may be at least partially corrected by their addition to sprays, so that we know that leaves can absorb them. Incidentally, Florida has pioneered in this line of research endeavor.

Iron and boron are rather dangerous when applied as sprays with some crops because of relatively low requirements and because tolerance limits are narrow. There is evidence that mixtures of trace elements are somewhat safer than single element sprays in some cases.

PRESENT STATUS

Generally speaking the present status of the problem of trace elements on vegetables in Florida is something like this:

Magnesium. On soils needing lime, the use of dolomitic limestone takes care of the situation. On soils deficient in mag-

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nesium but with adequate calcium and of desirable pH range, Magnesium sulfate is used in the fertilizer, supplied in definite ratio as magnesium oxide.

Manganese. This element, as the sulfate, is used directly on the marl soils of the Homestead area, in annual quantities up to 100 lbs. per acre. It may also be used in the fertilizers on sandy soils of naturally high pH or that have been recently limed. In addition, it may be safely included in a spray application in quantities up to 4 lbs. per 100 gallons of spray.

Zinc. This element, again the sulfate, is often added to the spray, at 2 lbs. per 100 gallons. Response to zinc has been very definite on some vegetable crops. Toxicity symptoms appear quite readily if too much is used. Actually, no additional zinc sprays are required on crops which are sprayed with the new zinc fungicides—in fact, zinc toxicity has been known to develop on tomatoes and other crops when such fungicides are used exclusively.

Copper. Prior to the introduction of the zinc fungicides, none of the vegetable crops on mineral soils developed copper deficiency symptoms, or at least copper deficiency was never a major problem on such soils. Crops such as tomatoes, peppers, potatoes, etc. regularly received copper fungicidal sprays. Apparently the older agricultural soils had adequate copper residues to carry crops through the first several years of zinc fungicides, but copper deficiencies appeared rapidly on virgin soils brought into production and sprayed only with zinc fungicides. Whether zinc additions actually intensify copper deficiencies, or whether the copper need is relatively high in its own right has not been determined. In any event, copper nutritional or fungicidal sprays are required on most vegetable land newly brought into production. To some extent, definite ratios of copper in the fertilizer are used.

Iron. This metal, as the ferrous sulfate in spray applications, will quickly correct the deficiencies sometimes encountered on limed soils. It has not been possible to establish an absolutely safe spray strength, however. One lb. to 100 gallons will usually relieve the deficiency, but sometimes marks tomato or other fruits to an economically damaging extent. There seems to be less tendency for such damage to appear when other trace elements are included in the spray mix. Apparently the iron carbamate fungicides are safe on these crops, but they do not have much effectiveness against most major vegetable diseases in Florida. Where they are used, a definite nutritional response is sometimes evident.

Boron. Borax is the common source of boron used, and may be included in the fertilizer for crops with a high boron requirement, such as broccoli, cauliflower, lettuce and cabbage. An an emergency basis, borax is sometimes applied as a spray or drench. The upper safe limits have not been entirely established, but up to 2 lbs. per 100 gallons have been applied in this manner without damage.

Future Research Needs

The research approach of the past—that of testing out trace element additions by spray or in fertilizer to cope with emergency problems—is not comprehensive enough to satisfy actual commercial needs in Florida. Several trace element deficiency problems which caused tremendous economic losses have been solved in this manner. Among these are "cracked stem" of celery which is corrected by additions of borax, copper deficiency on the organic soils of the Everglades, and zinc and manganese deficiencies on a variety of vegetable crops grown on a wide range of soil types, to mention a few. Iron and magnesium deficiencies have also been recognized and corrected, but these conditions have been of less economic consequence in the vegetable producing areas.

There are still physiological disorders of vegetable crops of major economic importance which must be solved. The efficient utilization of certain nitrogen source materials is a practical, major problem here in Florida. The adjustment of pH, the method of water control (which is basically an aeration problem) and the balance of trace and major elements available are felt to be related to this nitrogen problem. Blossom-end rot of tomatoes and peppers and black-heart of celery are partially solved problems which need investigation as to trace element effects in relation to pH control and irrigation methods.

There is a fundamental background of research in plant nutrition to which we must tie our program. Physiologists have demonstrated that aeration of the soil solution influences manganese requirement; that the manganese—iron balance is of nutritional importance; that nitrogen source affects the need for trace elements and the balance required among trace elements. Length of day and intensity of sunlight enter the picture—in fact, trace elements are essential to all basic plant processes and need investigation from that point of view.

It is my feeling that we in Florida, of all states, need to make provision for fundamental research involving trace elements in plant nutrition. Our methods of irrigation, the length of day during the growing period and the soil types which we farm all influence the balance of trace and major elements required. To some extent at least, these problems are peculiar to Florida, and it is our urgent problem to solve them.

The vegetable producers of the state are being forced to move on to the less desirable soil types. Soil areas most suitable for vegetable production are now in general use; future expansion must be on the acid, poorly drained sands. Vegetable crops cannot be grown on such soils in anything like our economical manner until they are drained and limed so that the first requirement is to alter the soil to a condition more nearly comparable to that of the more suitable soils. Drainage and liming do this to some extent; certain physical characteristics cannot be so altered in any practical way, and we must learn to adapt to them. It is in this adaptation that we need to investigate the complex, controllable problems involving trace elements, irrigation methods, nitrogen source materials and other factors.

It would seem desirable and necessary that we here in Florida do some fundamental work on the nutritional relationships involving trace elements. The recognition of trace element deficiency symptoms, and the development of means for correcting these, has been a great step forward. It has resulted in important commercial advances in vegetable production in Florida. The reported literature on these phases is vast, and research on a field scale is quite general.

Only a few restricted laboratories are busy investigating fundamental nutritional relationships among trace elements and between trace elements and other factors that influence their need in plant nutrition. I believe that the growers of Florida would benefit very greatly if we could establish a program here to pursue such lines of investigation. I have reason to believe that many of our problems involving the quality of our vegetable crops could be solved—or at least understood—by investigating them in this manner. Trace elements, like other plant nutrients, have certain specific functions in plant nutrition. There are great gaps in our knowledge of these functions. In addition to these direct influences on plant growth, the physico-chemical properties of ions in complex water solutions are such that it is impossible to approach some of these problems by varying the concentration of only one salt in plant nutritional studies. We have great need to study some of these things, since day-length, irrigation methods, drainage, temperature and other variable factors are of practical importance here. This approach to the problems in the field of future research on trace elements could be expected to result in important commercial gains by our vegetable growers.

THE PROMINENT ROLE OF THE SO-CALLED TRACE ELEMENTS IN THE RECENT REHABILITATION OF FLORIDA'S CITRUS INDUSTRY

A. F. CAMP*

Inasmuch as Dr. Camp's discussion of the comparatively recent rejuvenation of Florida's Citrus Industry very largely through the judicious use of certain of the trace elements was almost entirely on the basis of a large series of excellent slides and no manuscript for the record was provided, this important subject can be reported only very briefly at this time.

Emphasis was given, of course, to the observations that had been made for many years of the quite appreciable benefits that always seemed to follow the liberal application of such natural organics as dried blood or tankage, the extent of certain physiological responses appearing to depend largely on the amount of the application even to a point where too much nitrogen obviously was suplied.

General decline continued in a large percentage of the groves of the State, however, until the first trials with zinc in Gainesville, as reported in 1933, proved so extremely beneficial in curing, and of course preventing, the so-called frenching of citrus as well as the rosetting of pecan and the bronzing of tung trees. The results of zinc treatments were so dramatic that almost within the same season it became a general field practice.

Studies of the use of copper for the control of "dieback" or "ammoniation" in citrus revealed its complete effectiveness only a year or two later and both elements were promptly recognized as essential, each supplementing and neither replacing the other where both situations were involved in the grove. The general use of manganese rather quickly developed as did also the appreciation for the need for boron in restricted areas. Throughout all these studies iron deficiencies were recognized, as in the citrus groves of the East Coast Area, but its effective application has been found very difficult.

Continuing studies, therefore, are concerned largely with finding more effective, as well as more economical forms of these elements and methods of application as well gaining a better insight not only into their effect on gross yields but the composition of the fruit as well, especially from the standpoint of their use as human food. Ed.

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TRACE ELEMENT CONTENT OF LEAVES FROM TUNG ORCHARDS

MATTHEW DROSDOFF[1]

Inasmuch as no manuscript was submitted by the author it can be reported on only briefly at this time. However, it was published in Soil Science Vol. 70, No. 2, pp. 91-98, 1950.

It was noted that trace element deficiencies in relation to the growing of tung trees in the United States are particularly conspicuous in the lighter textured soils of Northwest Florida where the major acreage of this crop is grown.

Methods of foliage sampling, sample preparation and of analysis for five of the more important trace elements were described in brief detail and results reported on the basis of parts per million of the various elements in terms of dry matter involved.

The brief summary of this paper as published in the above referred to volume of Soil Science follows: "The zinc, copper, manganese, boron, and iron contents of representative tung-leaf samples are discussed in relation to the kind of soil on which the trees are growing and the kind and amount of fertilizer applied. Under all conditions observed, the range in zinc content of tung leaves was found to be 10 to 229 ppm., copper 2.5 to 12.4, manganese 25 to 2,884, boron 38 to 226, and iron 35 to 92."

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MINOR ELEMENT DEFICIENCIES OF DECIDUOUS FRUITS AND NUTS

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There are certain minor elements which must be provided for the best growth and production of deciduous tree fruits and nuts grown on most soils in Florida. The crops which will be discussed are the pecan, peach, pear and cultivated persimmon. Of these the pecan is the most important commercial crop in Florida, followed in order by peaches, pears and persimmons.

The need for zinc in the growth and production to correct rosette of pecans in the South was first shown about 1932 by J. R. Cole, Pathologist, U. S. Pecan Field Station at Albany, Georgia, but at that time he was stationed at the U.S. Pecan Field Station, Shreveport, Louisiana. This was the year that Harold Mowry, Horticulturist, later Director, of the Florida Agricultural Experiment Station, showed that zinc was necessary to correct bronzing of tung trees.

Soon after these findings, work was started in Florida by the author, who investigated the zinc requirements of pecans in various parts of the state. It was shown that nursery as well as orchard trees must have zinc applied for growth to be free of rosette if there is not already sufficient zinc available to the plants.

In these investigations it was found that pecan trees would respond to zinc applied to the soil in which they were growing, if needed, in all instances where such soils were otherwise adapted to pecan growth. Rates of zinc applied as zinc sulfate were worked out for several varieties of pecans in different parts of northern and western Florida. It was soon determined that, in cases of severe rosette, about five pounds of zinc sulfate applied to the soil in the spring would usually correct the disorder and, in the second year following application, the trees would begin to make normal growth. After this, about two pounds zinc sulfate annually per tree would generally provide sufficient zinc for normal growth in bearing trees. However, where bearing trees showed slight to moderate amounts of rosette, the two pound annual application was generally all that would be necessary for maintenance of normal growth and production.

During these experiments zinc oxide applied to the soil as the source of zinc was tested. It was found that zinc oxide proved satisfactory in causing trees to resume normal growth but required one or two years longer for the same degree of recovery than did zinc sulfate.

Zinc sprayed onto the foliage of pecans was developed as a satisfactory method of correcting rosette, by Cole and others.

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This proved effective also when tested in Florida. This is a very efficient way of applying zinc, since zinc sulfate can be added to the regular pecan sprays used for the control of insects and diseases, or it can be applied alone. Generally, four or five pounds of zinc sulfate to each 100 gallons of Bordeaux or other spray mixtures will correct rosette when sprayed onto the leaves in June. If zinc sulfate is used alone, the same amounts would be mixed with 100 gallons of water to which would be added about three pounds of hydrated lime.

Rosette is not a problem now in well-managed pecan orchards. Zinc is applied in some manner whenever needed. Many growers make a practice of applying zinc sulfate annually in the fertilizer as a maintenance program.

In sand and water cultures it was shown that boron was necessary for normal growth of pecan seedlings. The seedlings grow normally with 0.5 ppm of boron added with the nutrient solutions. Toxicity developed in the leaves of the plants with greater amounts of boron applied. It was found that there was a greater utilization of nitrogen also when the boron was added to the nutrients.

Following this work, borax was applied to 17 year old, low-yielding Stuart trees on the Experiment Station Farm in 0, ½, 1, 2, 4, 8, and 16 pounds per tree. The amount of boron present in the soil before the borax applications, was determined by H. W. Winsor of the Soils Dept., Florida Agricultural Experiment Station. The soil contained relatively low amounts of native boron, ranging from 0.09 to 0.18 ppm. The boron applied was readily taken up by the trees as shown by leaf analysis, but no benefits were obtained with any of the amounts of borax applied. However, toxicity showed up in the foliage of those that received four pounds and more of borax. The experiment was replicated four times and on two of the replicates the applications were repeated the second year with similar results. The tests were made in 1945 and 1946, and in the first year following that of each treatment only those trees which received the 8 to 16 pounds of borax showed toxicity in the leaves. By the second year the leaves on these trees cleared up and have since remained in good growth.

Large-scale experiments were initiated in commercial orchards in 1948 following preliminary tests in 1947. In these the applications ranged up to four pounds of borax per tree. No toxicity developed in the foliage, but no beneficial effects on growth and yields were obtained.

Magnesium, while not generally considered as a minor element, is included because there have been a few instances where it has been observed as lacking in pecan foliage. Tests have shown that trees will take up applied magnesium as revealed in leaf analysis but increased nut yields have not been obtained with its application.

Florida is not a large commercial peach producing state, but there are a few orchards of early maturing varieties and

small home plantings in many parts of the state. A condition known as little-leaf was noted quite universally in various young orchards and yard trees in 1938. R. D. Dickey, Asst. Horticulturist, Florida Agricultural Experiment Station, and the writer set up experiments in 1939 to determine the cause of this disorder. Zinc, manganese and magnesium were applied to the soil singly and in combination in the tests. Zinc and manganese were also tested in foliage sprays. It was shown that little-leaf of peach in Florida was caused by insufficient zinc available to the trees. In these experiments the condition was corrected with zinc applied either to the soil or as a spray to the leaves.

R. D. Dickey, in experiments with Pineapple pears, showed that zinc will correct a certain physiological condition which appears in the leaves of the trees. Trees tested responded to zinc sulfate applied either to the soil or to the leaves in a foliage spray.

Mr. Dickey has also reported on a chlorosis in the cultivated persimmon (commonly known as the Japanese persimmon), which apparently is caused by a zinc deficiency. With properly timed applications, the disorder responded to zinc made available to the trees.

As an over-all picture, satisfactory growth and production of deciduous tree fruits and nuts in Florida will often require applications of one or more minor elements. Growers who are alert watch for symptoms of deficiencies and apply the elements when and where they are needed. This, together with a general maintenance program which includes the growing of adapted cover-crops of legumes, and with additional adequate plant foods applied, have contributed to the production of these crops in Florida.

In presenting the paper, the different deficiencies were illustrated with colored slides.

MICRONUTRIENTS IN SUBTROPICAL FRUITS

JOHN L. MALCOLM [1]

The success or failure of subtropical fruits in Florida is determined to a large extent by the presence or absence of an adequate supply of the micronutrients. In spite of the extreme importance of these elements, there is very little known about the amounts of each of them necessary for the growth of these plants. A few of the more important plant species have already been subjected to investigation with regard to micronutrients. For many others, a cure-all spray has been developed which makes their growth possible. The soil in a large portion of the area suited by climate and elevation to the growth of subtropical fruits is highly alkaline and deficient in nearly all the elements except calcium. The soils of the remaining portion are sands which are deficient in even this element.

The alkaline soils are located south of Miami. They are derived from an oolitic limestone which contains very few impurities. The mineral fraction of these soils is 90 or more percent calcium carbonate with the balance made up of silica and iron oxide. It is the organic fraction which makes it possible for these soils to be used for agricultural purposes. The raw rockland, recently scarified, will have a pH of 8.2. Nevertheless with proper management good plant growth can be obtained. Once there is some shade, organic matter will accumulate on the surface. If this layer of organic matter is not mixed with the soil by cultivation, it will eventually become acid. Surface soil samples taken from groves in the Redlands had a pH of 7.0 to 7.5. An occasional sample was even more acid. Some hammock soils which were purely organic had pH values as low as 4.3 This acid condition has no permanence, however. Even old land with a thick layer of debris will lose its ameliorating blanket when exposed to direct sunlight.

In other sections of the State, suitable to the culture of subtropical fruits, acid sands predominate. These present an entirely different set of problems than the soils in the vicinity of the Sub-Tropical Experiment Station. As a result, the problems connected with subtropical fruits in these acid sands have been somewhat neglected. The practices recommended for citrus culture have usually proved adequate in these areas. The Plant Introduction Garden of the Bureau of Plant Industry and the experimental farm of the University of Miami are also in the alkaline soil area, which is unfortunate.

At present avocados and mangos are the most important subtropical fruits in Florida. The micronutrient requirements of these trees have been studied in some detail in the field and under controlled conditions. Although both of these fruits are important in other countries and have been subjected to study in those

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countries, most of the work on nutrition has been undertaken in Florida or California. Papayas, guavas, and some of the lesser fruits have been subjected to preliminary investigation and are grown successfully. The pineapple has been thoroughly studied in Hawaii and Puerto Rico, but very little of the information obtained under those conditions is applicable to its culture in Florida.

Successful grove culture without the use of micronutrient sprays has not been possible in the Homestead area, since the organic nitrogen fertilizers are no longer available or prohibitively expensive. Backyard trees and an occasional pothole planting will succeed without these sprays but no extensive planting is known where the trees are in the best condition without such sprays. Favorable response has been obtained to nearly all of the elements except iron. Zinc deficiency was the first nutritional disease of avocados to be described. The latest to be described in the Homestead area is the result of boron deficiency.

Little-leaf of avocado, the disease caused by severe zinc deficiency, was first described by Coit (1) in California. A complete description of this disease was given by Parker (4) in 1936. Ruehle (5) recognized this deficiency in Florida in 1938 and corrected the trouble with a foliage spray containing 10 pounds of zinc sulfate and 5 pounds of hydrated lime in 100 gallons of water. Sprays of manganese and iron salts on trees in the same grove did nothing to improve the condition of the trees. Ruehle (5) observed that zinc deficiency symptoms were much more severe in dry seasons and in groves where inorganic sources of nitrogen was used in the fertilizer program.

Copper deficiency in avocados was reported by Ruehle and Lynch (6). This occurred on newly-cleared, acid, sandy soils in Highlands County. The trees were young and in the early stages of the disease, appeared starved. The old leaves became dull and the veins prominent. In the next stage, the old leaves were shed and the branch tips died back. Multiple budding was a common symptom. An application of copper sulfate to the soil at the rate of two ounces per tree was sufficient to correct the condition. The use of manganese sulfate or mixed fertilizer without copper aggrevated the condition. Bordeaux or a neutral copper spray was suggested as a remedy for the deficiency but was not tested.

Two varieties of avocado were studied in sand culture by Furr, Reece, and Gardener (2). They described nitrogen, phosphorus, potassium and magnesium deficiencies, as well as the micronutrient deficiencies boron, copper, iron, manganese, and zinc. In the relatively short time their experiment was carried on, severe copper and zinc deficiency symptoms as reported by Ruehle (5) and Ruehle and Lynch (6) did not develop. Iron chlorosis was severe, with the young leaves almost free of chlorophyll. In the absence of manganese the older leaves commenced bleaching between the veins. This first appeared as separate

spots but gradually only the veins remained green. The leaves also became chlorotic when boron was withheld. The leaves fired at the margins and dropped prematurely. New shoots were short with small leaves. At the end of the two years of the test, dieback was already commencing. This has not been reported under grove conditions. Recently Dr. Roy W. Harkness of the Sub-Tropical Station has found that darkening of avocado seeds was related to low boron content of the leaves. This condition was not found where the trees received boron as a soil treatment. Most embryos in seed of untreated trees were dead or injured; from the treated trees only half the embryos appeared defective.

Zinc deficiency in the mango was observed by Lynch and Ruehle (3). The symptoms were similar to those in the avocado. They were most severe after prolonged dry weather on trees that had been liberally fertilized. The leaves were small and thickened. In some cases they formed rosettes. The condition was corrected by a foliage spray containing 5 pounds of zinc sulfate and 2.5 pounds of hydrated lime in 100 gallons of water. At the last meeting of the Mango Forum, Dr. T. R. Robinson reported that fruit cracking of mangos of the Sandersha type was prevented by the use of borax at the rate of two ounces per tree on the sandy soils of the West Coast of Florida.

For the rest of some 1400 odd species of plants now growing at the Sub-Tropical Experiment Station, we have no very definite information. It is the practice to spray these plants several times during the year with a nutritional spray containing copper, manganese, and zinc. A typical spray mixture is suggested in the recently revised avocado bulletin, "Avocado Production in Florida," by Wolfe, Toy and Stahl, revised by G. D. Ruehle (7). They recommend three pounds of copper sulfate or the equivalent in one of the neutral coppers, two pounds of zinc sulfate, two pounds of manganese sulfate, and sufficient hydrated lime for their neutralization, in 100 gallons of water. It may not be advisable to include the manganese in the spray more often than once a year.

This nutritional spray is recommended for use on plants in the Rockdale soils. Recently it was used in the greenhouse on Macadamia seedlings planted in regular potting soil. These seedlings developed a severe chlorosis almost at once. The chlorosis was corrected by spraying with a weak solution of ferrous sulfate but the plants were considerably set back before the nutritional balance was restored. On the acid soils throughout the rest of the State, soil treatments seem preferable to nutritional sprays. The elements applied in this way are available to the trees but do not have to be applied at such frequent intervals.

It is impossible to overestimate the importance of the micronutrients in the growth of subtropical fruits. Because of the inherent nature of the soils in the areas suitable for the growth of these plants in Florida, most of the elements must be supplied by the fertilizer or nutritional sprays. On the alkaline soils,

sprays have proved to be the only satisfactory method of application. On the acid sands, the required elements may be included in the fertilizer. The study of the problem of micronutrients in subtropical fruits has just begun, but it is a good beginning.

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ANIMAL RELATIONSHIPS TO TRACE ELEMENT NUTRITION UNDER FLORIDA CONDITIONS

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The so-called trace elements have made a very important contribution to the success of all branches of Florida agriculture. As a result of this the public in general is perhaps more interested in these special elements and better informed about their importance than is characteristic of many other sections of the country.

Some regions are especially noted for their naturally healthy livestock. The Bluegrass region of Kentucky with its fine horses and the Shenandoah Valley of Virginia with its excellent cattle are typical examples of such areas. In these regions the major and trace elements are supplied by the natural soil in such proportions that there are no deficiencies or toxicities which appear in the livestock as an improper mineral balance.

In Florida there are areas of deficiency of both major (2)[2] and trace elements as well as some places where toxicity is found, due to excess of some of the latter. Even though phosphorus mining is a major industry in Florida, some native pastures are deficient in this element (4) (18) (20). In such areas cattle consume all of the skeletons from dead animals and often chew up every piece of wood or lumber brought into the pasture from some other place. In other areas the cattle often chew oyster shells or other calcareous rocks indicating a craving for lime or calcium (5). Dairy cattle or beef cows nursing calves show these effects of lime deficiency more quickly than dry cows or steers, due to calcium being secreted in the milk. This secretion ocassionally is accomplished by the removal of calcium from the bones causing them to become thin and brittle and easily broken. Frequently trace element deficiencies appear in herds also deficient in phosphorus and calcium (3).

Inadequate nutrient diets especially during the winter months are often associated with trace element deficiencies. Minerals are essential to such animals but are not a substitute for total digestible nutrients nor for unbalanced rations due to lack of protein.

Florida cattle suffering from mineral deficiencies are often seriously handicapped by parasitic infestation. Under such conditions the animal fails to respond to worm treatment alone or to minerals but must have both conditions corrected to attain normal growth or production. Since some internal parasites are harbored by most Florida cattle and since clinical cases of para-

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[2]—Reference is to Literature Cited at end of paper.

sitism are not common in cattle on adequate rations, the best control for internal parasites is to be sure the animal has an adequate ration, including digestible nutrients and minerals.

The natural feed for cattle is pasture grass. Cattle should be able to get all of their requirements of feed and trace elements from the pasture, if supplied with some salt, calcium and phosphorus. Before it was known how much copper cattle required in the Everglades, the cattle were maintained by feeding cottonseed meal. Trace element problems can be handled by shipping in Prairie hay or other feeds to feed the cattle during the winter. Some cases have been observed where trace element problems were intensified due to the molybdenum content of alfalfa hay shipped into Florida.

The most common and satisfactory method of getting trace elements to Florida cattle is the mineral mixture box (2). The salt requirement of Florida cattle is less than that amount usually considered to be normal. When mixed with bone meal the salt acts as a preservative for the bone meal and the bone meal dilutes the salt making the combination more palatable than either one alone. The trace elements can be added readily to this combination.

To increase the palatability of mineral mixtures some have added feeds such as cottonseed meal, corn meal or molasses. A few very satisfactory mineralized pellets have been produced and used.

The cattleman must see that the minerals are kept dry in the box; that they are kept fresh by frequent refills; and that the height of the box is such that all animals can reach them easily.

A satisfactory mineral mixture must be made available at a reasonable price. To keep the cost of the mineral mix at a minimum there should be included only those materials known to be lacking in the feed and these in adequate but not excessive amounts. A commercial concern should not attempt to sell a cattleman any mixture that does not meet the needs of the cattle in the area, nor one that contains some inert, unnecessary, or even harmful material in order to reduce its selling price.

One of the complications of understanding mineral mixtures is the difference between the registration tag and the percentage of each material included in the mixture. Many cattlemen read the list of elements included on the tag but do not understand the meaning of the figures representing the guaranteed analysis. When copper sulfate, for instance, is used as the copper source, each one percent copper sulfate adds 0.25 percent of copper element. This allows some dealer representatives to sell mixtures containing the correct elements but in quantities which do not meet the needs of the animals in certain areas.

The several trace elements necessary for Florida cattle are used by the animal in one or more ways. There may be a simple deficiency to be met. The particular element may be a necessary

catalyst in the assimilation of other necessary elements. There is strong evidence that some, such as cobalt, may be involved in supplying necessary nutrients for essential digestive flora. In the case of copper and molybdenum, the higher rates of copper are necessary to a large extent to counteract the toxic effect of excessive molybdenum, found in some forages. Experiments have not successfully differentiated between the symptoms of copper deficiency and those of molybdenum toxicity. Some areas have been found to be copper deficient where molybdenum has not been demonstrated in amounts known to be toxic. Cattle in these areas respond to high rates of copper consumption in the absence of toxic levels of molybdenum. Several years ago a few cattle from the Moore Haven area responded to aluminum (13). Most of the cattlemen in that area continue to use aluminum in their salt mixtures.

Iron in the form of red oxide has been used as a constituent of the mineral mixture fed Florida cattle for a number of years. Some areas may need this iron while other areas have adequate iron in their forage and drinking water. It is possible that part of the response to the 25 percent red oxide used in the salt mixture was due in some areas to the presence of other elements in the red oxide, such as cobalt and aluminum. The red oxide of iron contained nearly 3 percent aluminum.

The inter-relation and inter-dependence of these trace elements is important as well as the compound from which the element is derived. Experiments with copper illustrate the importance of knowing the relative effects of different compounds. A solution of copper chloride containing 10 mg. copper per 10 ml. water using the 10 ml. dose intravenously at 10-day intervals successfully cured advanced cases of copper deficiency. Copper sulfate ($CuSO_4 . 5H_2O$) given orally in 5-gram doses at 10-day intervals will correct copper deficiency. Copper oxide and basic copper sulfate will also correct copper deficiency when administered at the same copper level as contained in 5 grams copper sulfate. Metallic copper is now under trial and another copper product called "copper cement" will be tried later.

Soil treatments with copper sulfate at the rate of 100 pounds per acre produced grass which readily corrected copper deficiency for about two years, after which this curative effect was lost. This illustrates the futility from an economic standpoint of attempting to alleviate the trace element deficiencies entirely through soil amendments, at least under certain conditions.

Some cattlemen have dusted their pastures with copper sulfate by plane using 10 to 20 pounds per acre. Cattle grazing this grass get a large but uncertain dose of copper. Other cattlemen have added copper to the drinking water. It usually is possible to separate from the herd a few individual animals that require special attention and treatment with trace elements.

The extent or limits of copper deficiency in Florida are not well defined (21). Regions of greatest need are the muck areas

Figure 1.—Grade Devon heifer (EES. No. 129) at about 6 months of age showing early symptoms of typical copper deficiency, i.e. swollen ankles front and back, rough hair coat and uncomfortable posture even before scouring bleaching of hair coat or much loss of condition has occurred.

but copper deficiency is prevalent in most of the east coast areas from Palm Beach County southward. Cattle in the Arcadia area respond to extra copper. Many of the cattle from LaBelle southward show copper deficiency symptoms sometimes excessively under uncontrolled conditions.

Under certain conditions copper sulfate is toxic. One 500 pound steer was destroyed by chronic copper toxicity after 122 daily doses of 5 grams copper sulfate (14). The same amount of copper as copper oxide was administered to 2 steers daily for 15 months without developing any symptoms of toxicity.

Molybdenum toxicity has been mentioned as being similar to if not identical with copper deficiency. The other trace elements which may be toxic under certain conditions are cobalt and fluorine (6). Rare cases of over dosage with cobalt have been reported. An animal might have to consume 20 times its requirement to produce any undesirable effects. Fluorine is present in raw rock phosphate in sufficient amounts to severely affect the teeth of cattle. Defluorinated phosphate is used safely in mineral mixtures when prepared so that the fluorine content is less than 0.2 percent.

Several elements have been fed experimentally to Florida cattle without obtaining beneficial results. Arsenic was thus tried orally as sodium arsenate and intravenously as sodium cacodylate. A slight stimulation was the only measurable effect on the animals. Neither potassium as saltpeter or phosphorus as sodium phosphate were effective in improving the condition

Figure 2.—ABOVE: Devon calf (EES. No. 547) with congenital copper deficiency shown by stiff bent ankles, most severe in front. Note appearance of severe pain while trying to move. Photo taken before copper therapy was started.

BELOW: Same calf as shown above after having received 4 weeks of copper therapy which involved drenching with 1/10 gram of copper sulfate in 6 oz. water twice a week. As a result of this treatment this calf developed into a mature cow normal in every respect.

Figure 3.—Scapula of steer showing typical symptoms of copper deficiency locally known (Florida) as "Pacing." Note advanced disintegration of periosteum and even the bone structure in the darkening and darkened areas, respectively. A second steer showing the same condition which was slaughtered at the same time showed identical bone symptoms. Two other steers, which were similarly crippled at the same time, recovered fully as a result of proper copper therapy.

of cattle suffering from what is now known to be primary copper deficiency.

Symptoms of trace element deficiencies are generally similar regardless of which elements are lacking. With cobalt deficiency the animal suffers from anorexia (loss of appetite). With copper deficiency this symptom is absent and some animals develop the pacing gait, caused by inflamation of the periosteum of the scapula and the interior of joints in the legs.

Cobalt is a deficiency element on sandy soils more than it is on muck soils, consequently more cattle in Florida suffer from this deficiency than any other trace element (17).

There are some indications that other trace elements should be given to Florida cattle besides cobalt, copper, and iron. Consideration must be given for needs of aluminum, magnesium, zinc, manganese, and perhaps boron as well as some others. Some of these may be in the bone meal and, therefore, included in the mixtures being used.

To make a salt mixture which will meet the needs of cattle in all parts of Florida may not be possible or practical. Such a mixture should contain enough of each trace element to correct the deficiencies but not enough to create hazards of toxicity. This must be based on records of rates of consumption and the actual requirements of the animals as determined by careful test.

A mixture containing the following amounts has some ad-

vantages in much of Florida particularly in the southern part of the peninsula:

50 pounds steamed bone meal
45 pounds salt
2 pounds copper sulfate
1 pound copper oxide
2 pounds aluminum sulfate
1 ounce cobalt carbonate

The analysis tag for this mixture would read:

Calcium (Ca)	13.00 percent
Phosphorus (P)	6.00 percent
Salt (NaCl)	45.00 percent
Copper (Cu)	1.27 percent
Aluminum (Al)	.20 percent
Cobalt (Co)	.03 percent

Some might want to add iron to this mixture. Perhaps the cost could be reduced if part of the calcium and phosphorus came from the defluorinated phosphate. These additions, however, would reduce the palatability and consumption rates.

As this formula stands there is no danger of copper toxicity because three-fifths of the copper is from oxide and two-fifths from sulfate. Only the sulfate is toxic and 0.5 percent of copper (Cu) from this source is well within the limits of tolerance. If the animal needs more than that amount the 0.75 percent from the non-toxic source of copper oxide is available without danger of injuring the animal.

The highest rate of consumption on our records for approximately this formula is 40 pounds per animal annually. At 1.25 percent elemental copper this is an annual consumption of 0.5 pounds of the element. This is equivalent to about 3 grams $CuSO_4$ average daily intake for one year. The animals consuming this amount remained normal in every way.

Continuing research probably will indicate that cattle need other trace elements. Manganese is one which has been studied However, sufficiently definite results were not obtained to indicate that it should be included. While these studies are being continued a mineral mixture similar to the one given should keep the cattle of Florida in reasonably good health.

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SOME ESTIMATES ON THE AMOUNTS OF SECONDARY PLANT FOODS USED ON FLORIDA CROPS

J. J. TAYLOR*

An attempt has been made to determine as closely as possible the approximate amount of secondary plant foods used in Florida agriculture during the past year. Several manufacturers were requested to furnish us information as to the tonnage used in their manufacturing of mixed fertilizers on the following items: copper, manganese, zinc, boron, iron and magnesium.

The several manufacturers who sent us reports gave a total tonnage of magnesium in its various forms as 15,943 tons. Since magnesium was by far the largest single item, it may be of interest to show that of this total 13,755 tons were sulphate of potash with magnesia, 1,335 tons of magnesium sulphate (Emjeo) and a small tonnage of seawater magnesium oxide, magnecite and brucite. This does not include dolomite.

Other secondaries were Copper sulphate 1,641 tons, Manganese sulphate 2,654 tons, Zinc sulphate 326 tons, Iron sulphate 496 tons, Borax 288 tons, making a total tonnage of secondary plant foods of 21,348 tons. The companies which reported these figures to us put out a combined tonnage of approximately one-third of the total tonnage of the State.

Assuming that the other manufacturers of the State used secondary plant foods in their mixtures in approximately the same proportion as those reporting, it would indicate that between 60 and 65 thousand tons of secondary plant foods are going into mixed fertilizers each year in Florida.

*—State Chemist, Chemical Division, State Department of Agriculture, Tallahassee, Florida. This communication was in the form of a letter to the Secretary of the Society.

THE RELATIONSHIP OF TRACE ELEMENTS TO THE GROWTH OF AGRICULTURAL PLANTS IN THE WESTERN STATES

FRANK E. GARDNER*

In view of the fact that the time of our meetings in June conflicted with certain National and International meetings in both plant and animal sciences it was not found possible to have a representative from the West Coast either prepare a paper on the above subject or be present in person for its discussion. In consequence of such a situation, Dr. Gardner very kindly agreed, on very short notice, to give a purely extemporaneous review of the work that has been done out there and is under way at the present time. This he was able to do very well indeed because of his personal responsibility for the USDA Sub-tropical Fruit Program in California and Florida, with headquarters at Orlando, and because of his quite intimate knowledge of past accomplishments and present activities in the field of plant physiology in both sections of the country.

In his brief review, Dr. Gardner of course dwelt at some length on basic work in plant nutrition that has been done in the west during the past quarter century by an extensive sequence of brilliant workers stemming from the time of Dr. C. B. Lipman and his contemporaries and also covered many of the practical applications of this work in the field where it has done so much for culture of such perennials as citrus, walnuts and olives as well as many other horticultural crops and farm crops. Ed.

*—Principal Horticulturist in charge of Sub-tropical Fruit Investigation, U.S.D.A., Orlando.

REGIONAL REPORT ON TRACE ELEMENTS IN PLANTS AND SOIL IN THE NORTH CENTRAL STATES

ROBERT E. LUCAS*

Before discussing trace element studies for the North Central States, I must state that our work is behind the research here in Florida. Much of our findings are no more than facts confirming your observations.

Only in the last decade have we realized the extensive need for the major plant nutrients, N-P-K. When I was attending Purdue during the late '30's, we were instructed that properly fertilized corn should get 75-150 pounds per acre of 0-14-7, and wheat 150-200 pounds per acre of 2-12-6. What a change has come about both in the amounts and in the formulaes! It is no wonder that trace element research has been neglected. Now that crop specialists have major nutrient problems reasonably evaluated, they are beginning to broaden their interest and include trace element studies. From the investigations already made, we are finding that not only may a lack of certain trace elements affect crop yields, but it may also cause malnutrition in animals. Another reason for our neglect in trace element research is the difficult task of determining the amounts present in plant material and in the soil. The use of new spectrographic techniques and the colorimetric methods are overcoming this quantitative problem.

Of the states in our area, Michigan has probably contributed the most research in trace elements. According to Dr. J. F. Davis,** members of the Michigan State College Soil Science Department have published over 50 papers and reports on this subject. At the present time nearly 40 crops are listed as needing trace element fertilization. Many of these recommendations deal with crops grown on muck soil. The organic soils in Michigan amount to approximately five million acres. Of this acreage only a small part is now under cultivation. However, that under cultivation often needs one or more trace elements for maximum crop growth. On the mineral soils, alfalfa, beans, and sugar beets often need trace element fertilization. There are large acreages of these crops in Michigan.

Dr. K. C. Berger** informs me that the consumption of trace elements in Wisconsin is constantly increasing. This is particularly true of borax. He believes that nearly two-thirds of the acreage in alfalfa shows boron deficiency. In 1949 over 1000 tons of borax were used. The use of other trace elements has not been as spectacular but they have a need for manganese on

*—Agronomist in charge of research, Wm. Gehring, Inc., Rensselaer, Ind.
**—Private communication.

the alkaline (calcareous) soils, particularly for oats and wheat.

Dr. Ohlrogge, reporting for the Purdue Agronomy Department, stated that about one-fourth of their fertility funds are for minor element studies. He felt the proportion was a fair balance with other fertility problems, and he did not expect much of a change in the near future.

In general the trace elements which give us the most trouble are boron and manganese. Both elements are usually deficient on over-limed and calcareous soils. Boron deficiency is corrected by mixing borax in the fertilizer at the rate of 10-25 pounds per acre. Because the amounts are small and the material inexpensive boron may soon be a standard recommendation for all alfalfa and beet fertilizers. Manganese deficiency is corrected either by applying as a fertilizer (50-100 pounds per acre of manganese sulfate) or as a spray (3-10 pounds per acre). The use of sulfur and acid forming fertilizers may be recommended by some crop specialists.

Recently the need for copper is being recognized on soils other than organic soils. Berger reports that sweet corn responds to this element when grown on some Wisconsin sandy soils. In 1949 our organization lost about 50 acres of wheat because of a severe copper deficiency. The soil type was a Newton sandy loam. This wheat followed a good potato crop. If we would have used Bordeaux instead of Dithane as the fungicide for potatoes we would not have observed the trouble in the wheat. Incidentally, test spray plots on the wheat foliage showed that molybdenum stimulated growth as well as copper.

The use of zinc as a fertilizer is not common in our area for seldom does one see zinc deficiency symptoms on crops; nevertheless, the use of zinc fertilizers and sprays does improve the yield and quality of produce. We are observing the benefits of zinc more since we have been using it in our fungicide sprays. The findings of Hoyman in North Dakota on potatoes well illustrates plant stimulation due to zinc sprays.

In the past our work with trace elements has been mostly field experiments, describing deficiency symptoms, and correlating soil factors which cause trace element problems. Such studies are fundamental, but they do not answer the role of trace elements in plants. We have practically no information on what effect trace elements have on the animals that consume feeds which contain various amounts of trace elements. The inter-relationship of trace elements in plants is also a field which needs greater study.

Using trace elements in our fertilizer is causing some manufacturing problems. One is the tendency to express the amount in fertilizer as the per cent carrier in the fertilizer rather than as the elemental form. Another problem is, how are we to label the bag for N-P-K when trace elements are added? Most states require that the manufacturer adhere strictly to the rule in that

[*]—Private communication.

they sell only recommended formulaes and that the analysis be correct on a percentage basis. Since the proportions and the calls for trace elements are so variable, the fertilizer companies find it difficult to meet recommended formulaes and still keep down production costs. Recognizing this problem, the Michigan muck farmers have asked their state chemist to permit the sale of standard grade fertilizers that have trace elements added when requested. For example, if a farmer wants 100 pounds per ton of copper sulfate in his 0-10-20, then the company makes a mixture of 1900 pounds of 0-10-20 and 100 pounds of copper sulfate. An additional tag is then placed on the bag showing the correct formulation. Our organization used about 500 tons of fertilizer with trace elements added. We believe the system used by the Michigan people is clear and simple and helps keep down production costs.

The Wisconsin fertilizer people are trying to follow the system of mixing trace elements in high analysis grades and then selling the fertilizer as a medium grade. For example, 3-12-12 with trace elements is made from 5-16-16; 0-9-27, containing borax is made from 0-10-30.

Another question which often comes up is whether we should buy "mineralized" fertilizers (those containing all known trace elements) or fertilizer with only the requested trace elements added. Either practice has its good points. "Mineralized" fertilizers have paid returns on some crops because we failed to recognize the various trace element problems. On the other hand, such fertilizers are more expensive and one may be buying ingredients which are not necessary. Furthermore, certain crops like beets and alfalfa require quantities of boron which would prove disastrous for beans and small grasses. The same problem might be true for copper and manganese. According to Berger the inclusion of manganese in fertilizer would injure potatoes growing in parts of Wisconsin. In general, I feel that as we become more informed in trace elements, we will use them only for certain crops and soil types.

Our workers have recently become interested in the effect of trace elements upon quality. Those familiar with boron physiology know that a lack of this element in such crops as celery, beets, alfalfa, and turnips can markedly lower quality. Some of my study in trace elements has been to determine the effect of copper fertilization on the ascorbic acid and carotene content of plants. It was found that there was no effect in some crops while others showed definitely significant differences. The protein content of copper deficient plants was found to be high. Sherman and Harmer (Michigan) have shown that manganese deficiency may lower the ascorbic acid in plants. The sugar content of carrots and table beets was also found low when these crops were grown on copper deficient soils.

A series of 5 photographs is appended to show some of the plant responses that have been referred to above.

Figure 1.—Corn showing copper deficiency growing on acid muck in Indiana. Symptoms- yellow streaks on leaves. Top leaves may be solid yellow. Distinguished from zinc deficiency by absence of any white areas.

Figure 2.—Corn showing zinc deficiency growing on Newton sandy loam, Jasper County, Indiana. Symptoms—same as described for zinc deficiency of corn in Florida—characteristic white bud area. In advanced stages the lower leaves show purple color.

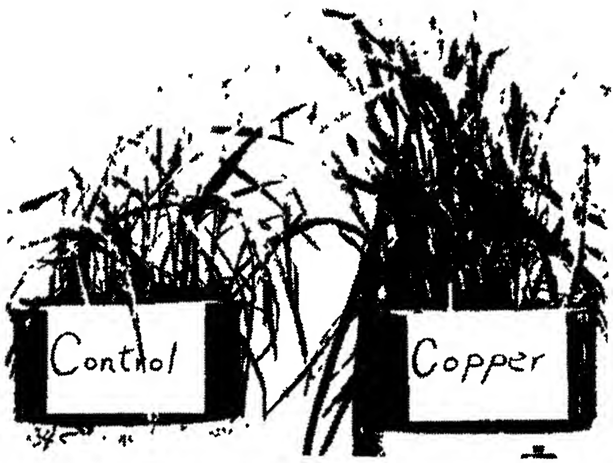

Figure 3.—Oats showing copper deficiency growing on muck soil in the greenhouse. Symptoms—light yellow cast to leaves with some streaking. Top young leaves show more yellow than older leaves and may fail to open from curl. Slight tip dying. Note: Deficiency symptoms of wheat show pronounced lemon yellow color. Distinguished from nitrogen and manganese deficiency by high nitrate nitrogen test and a noticeable dying at the end of the leaves.

Figure 4.—Check row in soybean field that had not been sprayed with manganese sulfate. This trace element problem is common in over-limed soils of Northern Indiana. Symptoms—lemon yellow to nearly white leaf color, especially on young leaves. Slightly affected leaves show prominent, dark colored veins. Photo courtesy of the Agronomy Department, Purdue University.

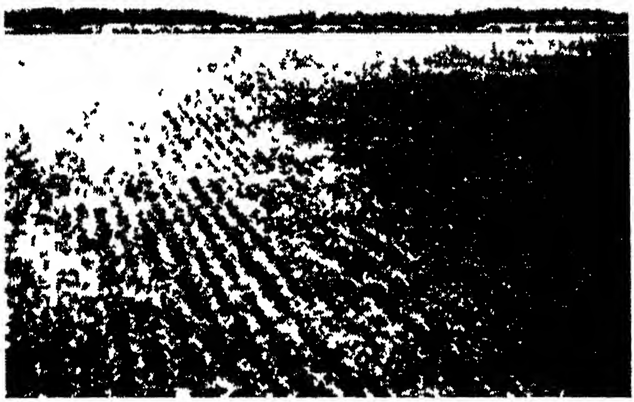

Figure 5.—Marked effect of soil fumigation with Dichloro-propene (Dow Fume N) on the growth of wheat. Light area on left not fumigated; dark colored plants on right fumigated. The actual response was a correction of manganese deficiency.

TRACE ELEMENT RESEARCH IN THE NORTH EASTERN STATES

E. R. PURVIS[1]

According to a recent survey (1), 12 trace elements have been investigated by the various Experiment Stations of the northeastern states. Beneficial results have been obtained from field applications of salts of boron, copper, iron, manganese, molybdenum and zinc to certain crops. To date, negative results have been obtained from plant studies with cadmium, chromium, cobalt, iodine, strontium and vanadium. Forage plants have been found to contain insufficient cobalt to meet animal requirements in some areas of New Hampshire, New York, Massachusetts, and Vermont.

Boron

Boron is the trace element most commonly found to be deficient in the soils of this region and alfalfa the crop most widely affected. Apples have responded to applied borax in Connecticut, New Hampshire, New York, Rhode Island, Vermont and West Virginia. Beets, broccoli, cabbage, cauliflower, celery, Ladino clover, tomatoes, and turnips are other crops often found to suffer from insufficient boron. A small increase in the yield of potatoes due to applied borax has been reported from Pennsylvania.

It is likely that most of the soils of the northeastern states are deficient in available boron—at least during certain periods of the year—for the growth of crops having a high requirement for this element. During the dry summer of 1949, boron deficiency was observed for the first time in alfalfa growing on some of the heavier soil types in Northern New Jersey. Prior to this time, these soils had been thought to contain sufficient available boron for normal growth of alfalfa. Similar reports of the effect of drouth in producing boron deficiency have come from Connecticut. The Storrs Station reports that they have yet to test a Connecticut soil by the pot-culture method and find sufficient boron for the normal growth of turnips.

All states of the northeast recommend borax for alfalfa when grown on soils known, or suspected, to be deficient in boron. These recommendations vary from 20 pounds of borax per acre annually to 40 pounds applied once in the alfalfa rotation. The borax is usually mixed and applied with fertilizer. Such applications have become so common that most fertilizer companies operating in the area offer standard mixtures containing borax for alfalfa. In the 6 states where boron deficiency in apples

[1]—Prof. of Soils and Research Specialist in Soils, N. J. Agr. Expt. Station, New Brunswick, N. J.

has been identified, from 2 to 8 ounces of borax per tree, depending upon tree size, is recommended. Such applications are repeated every 2 or 3 years. Recommendations for vegetable crops vary from 10 to 40 pounds of borax per acre, depending upon the crop and soil type. New Jersey recommends that all fertilizers contain 5 pounds of borax per ton and that fertilizer for tomatoes contain sufficient borax to supply 10 pounds to the acre.

Most state laboratories in the Northeast test soils for available boron. In New Jersey, 0.35 parts per million of available boron is considered the critical level below which crops are likely to respond to applied borax. Plant tests and the identification of deficiency symptoms are other methods employed for detecting boron-deficient soils.

Manganese

Manganese deficiency is probably the second most important trace-element problem of this area. Deficiencies of this nutrient have been reported on overlimed soils only. In most instances the pH of deficient soils exceed 6.5, although deficiency may occur at a slightly lower pH on light sandy soils. Vegetable crops, such as beans, beets, cabbage, cauliflower, and spinach, are commonly affected. There are instances, however, where the deficiency has been reported in alfalfa, apples, clover, corn, peaches, and the small grains.

Recommendations for the correction of manganese deficiency include soil treatment with manganese sulfate at the rate of 50 to 100 pounds per acre or spraying of crops with a dilute solution of manganese sulfate. In other instances the application of sulfur to reduce the soil pH is resorted to.

Manganese toxicity on acid soils has been reported in apples in West Virginia, tobacco in Connecticut, and in several lime-loving crops in Pennsylvania. Results from a study of the mineral composition of leaves from a large group of native plants in the latter State show that one of the chief differences between calciphile and calcifuge plants lies in their manganese content.

Copper

Copper deficiency in the Northeast is believed to be confined to organic soils and is most likely to occur during the first few years that such soils are cultivated. The deficiency probably affects all crops but is usually reported in vegetable crops since the peat areas of this section are normally planted to such crops. In New York, the thickness and color of the scale of onions were improved by applications of copper sulfate up to 300 pounds to the acre. Connecticut studies have indicated that applied copper may counteract manganese toxicity in alfalfa.

Iron

Iron deficiency rarely occurs on the normally acid soils of

the Northeast. The deficiency does appear, however, when some soils are overlimed. Iron deficiency has been reported in vegetable crops growing on Connecticut soils that received heavy applications of wood ashes. New York reports the deficiency in blueberries and in most tree fruits grown in high-lime spots. Spraying with a 1 per cent solution of ferrous ammonium sulfate is recommended for deficient blueberries. In New Jersey, the injection of iron salts into the trunks of affected trees is recommended for correcting iron deficiency in pin oaks.

Zinc

Response to applied salts of zinc have been reported with potatoes in Maine and with corn in Maryland. Great variation has been found in the available zinc content of New Jersey soils and recently zinc deficiency in apples and peaches has been reported in this State.

Molybdenum

Considerable work with molybdenum has been done in New Jersey during the past 2 years. The total molybdenum content of samples from 18 important New Jersey soils was found to vary between 0.8 and 3.3 parts per million. Alfalfa from a number of locations was found to contain from less than 0.1 to 1.4 parts per million of molybdenum on the dry-weight basis.

Significant increases in yield have been obtained from applications of 1 pound sodium molybdate per acre in 5 out of 6 field tests with alfalfa growing on some of the heavier soil types. These increases ranged as high as 27 per cent and averaged 13 per cent for all tests. The molybdenum-treated alfalfa was found to contain appreciably more nitrogen than untreated plants in 4 of the 6 tests.

Results from greenhouse pot tests indicate that one of the principal benefits of liming upon the growth of alfalfa may lie in the release of molybdenum from the soil. Working on the theory that plants grown on acid soils may have difficulty in obtaining sufficient molybdenum, a remarkable response was obtained in a greenhouse test in which potato seed pieces were dipped in an 0.10% solution of sodium molybdate. An increase in tuber production of 87% was obtained. This treatment is being tested in the field at 6 locations in New Jersey this season.

Recently the New York Station has reported that molybdenum teatment eliminated "whiptail" in cauliflower when applied to acid Long Island potato soil in a greenhouse test.

Current Trace-Element Research in the Northeast

Interest in trace-element research continues in all States of the Northeast. Most of the agricultural experiment stations of

Figure 1.—Response of Katahden potato to treatment of seed piece with molybdenum shown growing under greenhouse conditions in a Nixon sandy loam with a pH of 5.2 and a uniform treatment with NPK. Photo taken 107 days after planting.
LEFT—no treatment of seed piece.
RIGHT—seed piece dipped for 10 minutes in a 0.01 percent solution of sodium molybdate.

the area have active projects underway at present. The nature of these projects vary from surveys to find deficient areas to elaborate projects involving the work of a number of investigators. Projects of the latter type are under way in Connecticut, New York, and New Jersey. In the latter state, the soil and plant status of copper, cobalt, chlorine, fluorine, iodine, manganese, molybdenum, and zinc are each being investigated in one or more projects.

The physiological relationships existing between the various trace elements in plant nutrition are attracting more and more attention. The effect of copper in partially correcting manganese toxicity has been mentioned. There is evidence that the molybdenum requirement of legumes is increased on soils having a high available manganese content. Molybdenum salts have been found to partially counteract the toxic effects of heavy applications of borax to alfalfa. The relationship between the roles of iron and manganese in plants remains a controversial issue. The

importance of trace elements in the formation and activity of plant enzymes is being more widely recognized. All of these factors indicate that the blind application of trace-element mixtures on a "cure-all" basis should be viewed with caution. Such treatment may well create problems of a more serious nature than those it was intended to correct.

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PLANT RESPONSE TO TRACE ELEMENTS IN SOUTHEASTERN UNITED STATES

JAMES A. NAFTEL[1]

Soils, climate and crops of the South are such that trace elements are important in crop production. Large areas of the South consist of sandy or light textured soils, easily leached and with low organic matter content. The climate is characterized by relatively high temperature and rainfall. Crops grown include field, vegetable, fruit and tree crops, as well as many ornamentals.

During the past 75 to 100 years most of the crop land has been clean cultivated, thus exposing the soils to the extreme ravages of erosion, oxidation and other processes of soil nutrient losses. Many of the soils have been formed under conditions of extreme weathering and hence losses of much of their mineral content.

Recently through educational, economic, and governmental programs, large acreages of row crop land are being diverted to sod crops or what is now commonly referred to as "Grassland Farming." This trend toward sod crops will have significant effects on the needs and conservation of trace element plant nutrients since this development includes many leguminous plants that respond favorably to some trace elements.

Soil fertility investigations were begun at some experiment stations in the South more than 50 years ago. Major interest was in N.P.K. and lime during that time, which resulted in the well-known use of commercial fertilizers. Of the approximately 10 million tons used in the 13 Southeastern States in 1949, North Carolina alone used more than 1.8 million tons. The use of lime has not kept in balance with the use of the major elements; in large areas too little lime has been applied while in others excessive amounts have been used with unfavorable results.

Trace element studies in the South had their beginning about 25 years ago when it was found that certain observed abnormalities of crops were not avoided despite the use of the commonly used major plant foods and lime. Actually the first experience of the author was in the Florida Everglades during 1926-28 in connection with Cu deficiencies on peanuts. Reports on the early trace element studies were made by Allison, Bryan, and Hunter in 1927.[2] Interest and investigations of trace element needs followed a natural development in the field of soil fertility and plant nutrition in that chemical methods and technique had to be developed not only for detecting and estimating the content of B, Cu, Fe, Mn, Mo, Zn, etc., but also to prepare pure culture mediums for fundamental studies. From this beginning of trace element

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1—Agronomist, Pacific Coast Borax Co., Auburn, Alabama.

2—Allison, R. V., Bryan, O. C., and Hunter, J. H. Florida Agricultural Experiment Station Bulletin, No. 190 (1927).

studies in Florida, investigators in Alabama, Georgia, Kentucky, North Carolina, and Virginia reported on early investigations during the middle and late thirties.

Trace element studies in the Southern United States during the last two decades have in the main been in applied rather than in pure science in an effort to determine plant response to additions of single or combinations of trace element compounds to soils. Trace elements have been supplied to crops and soils by applications in the regular fertilizer mixtures or as direct applications in dusts or sprays singly or in combination with pesticides. Where there are specific recommendations for the use of trace elements for certain crops, the fertilizer manufacturer can incoporate the trace element into the fertilizer mixtures with a guarantee of analysis. Also where there is a general recommendation for the incorporation of minimum amounts of trace elements in all grades of fertilizers within a state, as some are now doing, the fertilizer manufacturer has no particular problem in compliance. The real difficulty in supplying trace elements is where prescription and varying amounts are requested by growers. There is an increasing interest in foliar application of trace elements, especially on fruit and vegetable crops where sprays and dusts for pest control are a matter of routine practice. The latter application can be made without much additional cost.

The present discussion, therefore, will be largely concerned with the response of crops to trace elements in the Southeastern United States. For convenience the trace elements, B, Cu, Fe, Mn, Mo., and Zn, are arranged alphabetically and will be discussed in this order.

Boron:—Soil contents of B in the Southeast vary from ample amounts in the heavier more fertile soils to deficient amounts in the light sandy types of soil. B deficiency may be induced by overliming on some soils.[3]

Alfalfa has been one of the most valuable farm crops in large areas of the country but was generally found to be unsuccessful in the Coastal Plains and areas of other sandy type soils of the Southeast until B was added in addition to lime and other fertilizers.[4] Now every state in the Southeast is producing alfalfa crops of from 3 to 5 tons of hay annually and using from 10 to 40 pounds of borax equivalent per acre in the regular fertilizer mixtures.

Other field crops on which favorable practical results have been obtained with B fertilization are crimson, bur, button, red, and white clover, sweet corn, sweet potatoes, and tobacco, the latter crop responding favorably to only 2½ lbs. borax per acre.

Boron has been commonly used on many truck crops in the

3—Naftel, James A.; Soil Liming Investigations: V. The Relation of Boron Deficiency to Overliming Injury, J. Amer. Soc. Agron. 29: 761-771 (1937).

4—Willis, L. G. and Piland, J. R.; A Response of Alfalfa to Borax, J. Amer. Soc. Agron. 30: 63-67 (1938).

Southeast since the early report of Purvis and Ruprecht[5] of the need for B addition to celery. Other vegetable crops quite commonly fertilized with B are beets, broccoli, cabbage, carrots, cauliflower, lettuce, radishes, rutabagas, tomatoes, and turnips. Generally boron at the rate of 10 lbs. borax equivalent per acre has been recommended for the vegetable crops, although the more recent investigations have shown favorable results with lower rates of boron such as 5 lbs. borax equivalent per acre.

Fruit crops in the Southeast that respond to boron are apples, citrus, and grapes. Boron deficiencies are corrected on apples by applying from 1/3 to 1 lb. of borax equivalent per tree as a direct application or with the other fertilizers. Where B deficiency has been noted on citrus in Florida, boron is supplied to trees either in the spray or fertilizer applications. Foliar and fruit symptoms of B deficiency on grapes were corrected in South Carolina vineyards by applications of 10 pounds of borax per acre.[6]

Copper:—Cu has been noted to be deficient in peat, muck, and other highly organic soils on the one hand and on sandy soils on the other extreme. Furthermore, organic and heavy soil types require and withstand more Cu than light soils. Due to the widespread use of sprays and dusts which contain Cu. there have been few clearcut examples of Cu deficiencies reported on crops grown in the field with the exception of those reported in Florida and in small areas of organic soils that contain high contents of lime.

Iron:—This element becomes a problem in plant nutrition on calcareous or alkaline soils. On some soils such as Sumter clay, which occurs in the black belt area of Alabama, Mississippi, and Texas, peanuts, common lespedeza, crimson clover and some grasses fail to make satisfactory growth due to iron deficiency. Soil applications of iron do not correct the deficiency but spray applications of iron compounds have given favorable results on experimental plots. On the other hand, small grains and Johnston grass appear to obtain sufficient iron on the above soil.

Iron deficiency has been recognized on citrus in Florida for a number of years but this is being covered in another report.

Ornamentals such as azaleas, camellias, roses, etc. often show iron deficiency when grown in soils with relatively high pH values; these deficiencies may be corrected either by spray application or by adjustment of soil reaction.

Manganese:—Soil acidity is one of the most important factors influencing the availability of Mn to plants. The strongly acid, sandy soils of the Southeast are most likely to be low in Mn, and when such soils are excessively limed, Mn deficiency may occur. The brown, chocolate and red soils often contain

5—Purvis, E. R. and Ruprecht, R. W.; Cracked Stem of Celery Caused by a Boron Deficiency in the Soil, Fla. Agri. Exp. Sta. Bul. 307 (1937).
6—Scott, L. E.; The Effect of Boron on Fruit Production, S. C. Exp. Sta. 54th Annual Rept.: 151-155 (1941).

high contents of Mn. The latter soils may contain sufficient soluble Mn to be toxic to some crops when the soil acidity is high.

Cotton, corn, peanuts, small grains, soybeans, and tobacco have been observed with Mn deficiency symptoms in some field soils of the Southeast. Recent reports by Shear and Batten[7] of the Virginia Station have pointed out the need for Mn applications on corn and peanuts where lime has raised the soil reaction above pH 6.0. Increases of peanuts of as much as 400% have been obtained by proper application of manganese sulfate of about 20 lbs. per acre. Truck crops such as beets, cabbage, cucumbers, peppers, spinach, and tomatoes have shown Mn deficiencies in the eastern truck belt from southern Florida to Maryland.

Molybdenum:—Although Mo has recently been recognized as an essential element for plant growth and some field trials of added Mo have given yield increases of alfalfa and certain clovers, no results have been reported in the Southeast.

Zinc:—This is another essential plant food element that may be deficient in some soils especially where liming has been excessive on soils of low Zn content. Corn has been the field crop in the Southeast that most commonly responds favorably to Zn application. Corn on light textured soils, heavily fertilized and with a high plant population quite frequently shows "white bud" or Zn deficiency in the early stages unless Zn has been supplied with the regular fertilizers or as a direct application. As a result of field tests with corn in recent years, Zn is quite commonly added as a regular part of commercial fertilizers.

Tree crops such as pecans,[8] tung nuts and citrus have shown Zn deficiencies which are commonly referred to as "rosetting," "bronzing," or "frenching," respectively. Corrective additions on Zn either in the regular fertilizers or in the spray and dust applications have proved practical remedies.

Application of Trace Elements to Plants:—The practical use of trace elements has received considerable attention in recent years, particularly is this true as to the most feasible methods of applications for correcting nutrient deficiencies. Direct application of trace element compounds to soils or crops in desired amounts either as single elements or in combinations of trace elements was formerly the general procedure. Now, some trace elements are applied for crops as a regular part of commercial fertilizer. More recently, trace elements have come into practical use as dusts or sprays on crops where the latter are regular parts of the crop management program. It may be expected in the

7—Shear, G. M. and Batten, E. T.; Manganese for Peanuts and Corn, Mimeographed series, Virginia Agrl. Exp. Sta. (1950).

8—Alben, A. C., Hammar, H. E., and Sitton, B. C.; Some Nutrient Deficiency Symptoms of the Pecan, Amer. Soc. Hort. Sci. Proc. 41:53-60 (1942).

future that more vegetable and fruit crops will receive their needed requirements of trace elements as a part of the pesticide application, thus avoiding some of the complications involved in soil reactions.

Problems Needing Study in Trace Element Research:—Future investigations on plant requirements of trace elements should include the following:

1. Interactions of one or more trace elements on the other.
2. Further studies on diagnostic techniques of trace elements.
3. Residual effects of trace elements applied to soils.
4. Efficient forms or sources of trace elements.
5. Optimum rates of applications of trace elements for the most efficient production of quality crops.
6. Improvement and calibration of soil and tissue methods of chemical analysis for trace elements.
7. Continued study of most efficient method of application of trace elements.

A series of 5 figures is appended to show some of the results that have been obtained thru the use of trace elements in the Southeast as referred to in the brief discussion above.

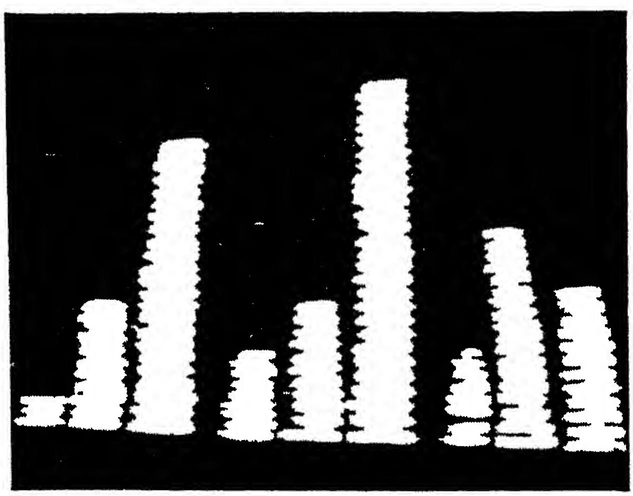

Figure 1.—Ears of sweet corn harvested from field plots in a boron experiment. The column of ears at the right in each category of treatment shows the relative yield of prime ears. Medium or imperfect ears are shown in the center and the nubs and immature ears are at the left. Fertility treatments uniform with the exception of boron. Photo courtesy Edisto Branch, S. Car. Agr. Expt. Station.

Treatment Right—no boron.
Treatment Center—5 pounds borax per acre
Treatment Left—10 pounds borax per acre.

Figure 2.—Yield of No. 1 sweet potatoes from different applications of boron. Right, none; center, 5 pounds borax per acre and left, 10 pounds. The yield per acre of marketable potatoes for each treatment was 153, 235 and 186 bushels, respectively. Photo through the courtesy of the Edisto Branch, S. Car. Agr. Expt. Station.

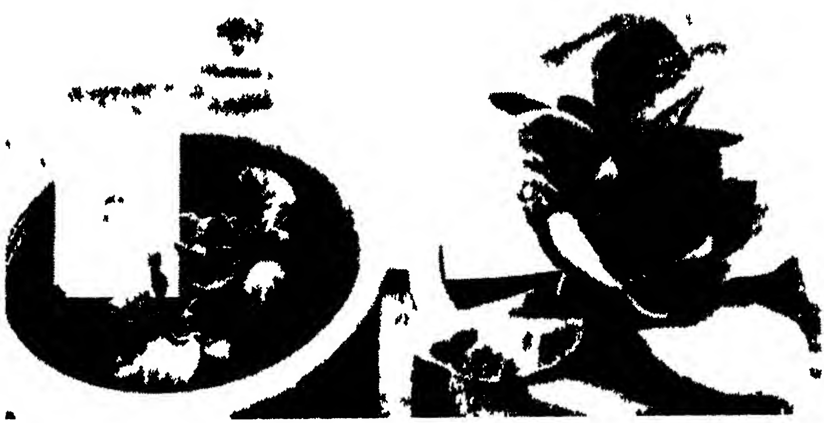

Figure 3.—Effect of boron on the growth of cabbage in a limed soil under greenhouse conditions. LEFT—No boron. RIGHT—Boron treated.

Figure 4.—Boron deficiency in cauliflower growing in Baldwin County, Alabama, as shown by hollowness and "browning" in stem on left in comparison with sound, firm condition in that on the right. Photo courtesy of Alabama Agricultural Experiment Station.

Figure 5.—Response of alfalfa to treatment of a high lime soil with boron. LEFT—20 pounds of borax per acre. RIGHT—no tıeatment. Photo courtesy Alabama Experiment Station.

EXCESS MOLYBDENUM IN FORAGE IN CERTAIN LOCALITIES IN CALIFORNIA*

HAROLD GOSS**

For many years, a cattle disease characterized by intense diarrhea, emaciation and change in coat color has been reported at intervals by ranchers on the southwestern edge of the San Joaquin Valley in central California. Much of this area is devoted to oil, livestock, alfalfa and cotton production. In recent years, cotton acreage has decreased and has been replaced by irrigated pastures. A number of different dairies are reported by the Farm Advisor's Office to have started between 1930 and 1940 in the affected area and failed because of this disease. Following Muir's (1) discovery in 1941 that the cause of scouring among cattle in the so-called "teart" pastures of Somerset, England, was due to an excess of molybdenum in the soil and forage, an investigation of the affected area in California by Britton and Goss (2) showed that plants in the pastures where excessive scouring occurred contained from 6 to 36 ppm. of molybdenum, while similar plants from normal pastures on the Davis Campus of the College of Agriculture contained only 0.5 to 1.5 ppm. molybdenum. Ferguson, et al. (3), and Muir (1) reported that teart pastures contained more than 14 ppm. while non-toxic pastures never contained more than 6 ppm.

Since our first report (2), a survey has been undertaken by W. P. Kelley and I. Barshad of the Division of Soils, of the occurrence of toxic quantities of molybdenum in pastures of that part of the state. The results of this survey, reported in part by Barshad (4) show the area affected to be much larger than susspected. Molybdenum contents as high as 193 ppm. were reported in some legumes from a newly planted irrigated pasture. A large number of suspected plant samples have been analyzed in the author's laboratory and we now have evidence which shows toxic levels of molybdenum in limited areas as far south as Death Valley Junction, one area to the west in Santa Barbara County, and as far north as Madera County. Samples of range grasses taken from various areas in the foothills of the Sierra Nevada have shown 3 to 6 ppm. which is not considered toxic. The highest concentration yet recorded, over 550 ppm., was found on the east side of the range in a section of Nevada.

Control of the molybdenum poisoning is being achieved by feeding copper sulfate to the cattle, either in salt or in the drinking water, in an amount which would bring the total copper con-

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sumed by the animal equivalent to 50 ppm. of the dry matter of the forage.

Although we had received no reports that sheep were affected in the same way as cattle, we have demonstrated that high molybdenum is toxic to sheep. We fed black sheep on a ration of barley and alfalfa hay to which was added sodium molybdate so that the total molybdenum concentration was 200 ppm. on the dry basis. Within 10 days to two weeks on this diet, the new wool over the whole of their bodies was observed to be coming in without the black pigment. After 15 weeks on this high level of molybdenum, there was a layer of grey wool 1 to 2 cm. thick on each of the black sheep. In a control experiment where the ration contained 200 ppm. molybdenum plus an addition of copper sulfate equal to 100 ppm. copper on the dry basis, there was normal pigmentation of the wool throughout the experimental period.

When 100 ppm. copper as copper sulfate was added to the experimental high molybdenum ration, the normal black pigmentation returned to the new wool fibers. These effects are illustrated in the photograph. Not only is the normal pigment absent in these "grey" wool fibers, but the physical properties are notably altered. J. F. Wilson is making a study of the affected wool fibers. No scouring of the sheep was noted in any of these trials on dry roughage.

In experiments with black horses and pigs, black chickens and turkeys and black rats, no change in coat color of the animals, or feather color of the birds was noted on high molybdenum rations.

Figure 1.—Cross section taken from the fleece of a black sheep to show the effect of molybdenum feeding. LEFT—Layer of grey wool 1-2 centimeters thick which appeared as the new growth during a period of 15 weeks when the animal was fed on a ration of barley and alfalfa to which had been added sufficient sodium molybdate to give a total molybdenum concentration of 200 ppm. on the dry basis. RIGHT—Normal black wool profile also showing how the black pigmentation returned to the wool fibers upon adding 100 ppm. of copper as copper sulfate to the diet containing the high molybdenum.

The disorder produced by excess molybdenum seems to be specific for ruminants.

Summary

The occurrence of excess concentrations of molybdenum in the soils of certain areas in California and Nevada has produced forage which is toxic to cattle. The toxicity is marked by excessive scouring and loss of coat color. In experimental feeding of black sheep on dry rations of high molybdenum concentrations, the new wool grows in without black pigment. No scouring was noted. Copper sulfate protects and restores the normal black pigment to the new wool and prevents the scouring and loss of coat color in cattle.

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SOME TRACE ELEMENTS AND ANIMAL RELATIONSHIPS IN THE EASTERN AND SOUTHERN STATES OF THE U. S. A.

GEORGE K. DAVIS

In this brief discussion of observations which have been made on trace elements and animal nutrition in the Eastern and Southern states, let me first list the states included.

Roughly the region is bounded by the Ohio and Mississippi Rivers to the West and the Atlantic Ocean on the East and extending North from the Gulf to the St. Lawrence. Including Ohio and Louisiana, there are 22 states in this area. As of this time experimental investigations of trace element deficiencies in domestic animals have been carried on in less than 10 of these states. Intensive studies have been made in New York, North Carolina, New Hampshire, and Ohio. On the other hand, practical farm observations have been reported from practically all of them.

Cobalt: Probably the observations on cobalt deficiency have been most widespread in this area. Cobalt deficiency, or response to cobalt supplements with animals under natural conditions in farm practice, has been observed in New Hampshire, Vermont, New York, North Carolina, Ohio, South Carolina, Virginia, Georgia, and possibly Maine. Conditions which could be associated with cobalt deficiency have been noted in other states, notably Louisiana, Mississippi, Maine and Kentucky, but even the dubious confirmation of response to cobalt in a mineral mixture has not been reported.

The close resemblance of cobalt deficiency symptoms and starvation for lack of total digestible nutrients makes identification difficult. Further, Beeson and associates at Ithaca, New York, have observed that alfalfa has always been found to contain an adequate nutritional level of cobalt. Thus, if alfalfa were given to poor cattle suffering from either cobalt deficiency or lack of total digestible nutrients, favorable response should result.

Two factors have led to the widespread use of cobalt supplements in mineral mixtures and feeds in the recognized deficiency areas and in many suspected areas of the East and South.

First has been the development of symptoms, including loss of appetite, weight loss, drop in milk production, anemia, failure to shed the old hair in the Spring, and indifferent reproductive performance, even when the total digestible nutrients were available in quantity if not quality.

Second has been the rapid improvement of such animals when

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fed cobalt supplements. This response has been observed where chemical analyses have failed to detect differences in the cobalt content of feed or animals. The low level of cobalt requirement in ruminants, 0.1 part per million in the feed, has made detection of deficiency situations quite difficult.

Cobalt deficiency has been well studied in North Carolina in cooperative work between the Regional Laboratory in Ithaca, New York, and the North Carolina Experiment Station at Raleigh, particularly in the coastal areas. Detailed studies have been carried out on plants, animals and soils. Cobalt is deficient here and response is obtained in cattle on those areas. In fact, cattle can be kept on those areas now which previously could not be expected to survive due to the low cobalt intake. The soil types in the coastal plain of South Carolina and Georgia closely resemble the deficient soils in Florida, and in these areas cobalt has given a response, although little experimental work has been carried out. It has been the experience of farmers and research men in commercial enterprises that the addition of cobalt gives a favorable response over large areas of these states.

Copper: Copper, which is also needed by cattle in many of these same areas, has given definite response to beef cattle and dairy cattle in the eastern part of Virginia. Presumably this deficiency has resulted from repeated cropping and possibly from practices which have caused a fixation of the copper. It has been reported as a deficiency in Kentucky, Louisiana and Mississippi.

In Kentucky areas, the copper deficiency is not complicated by the presence of molybdenum, but chemical analysis has shown forage copper levels as low or lower than one part per million. Similar observations have been made in Louisiana. The animals exhibit imperfect performance, breeding troubles and anemia, with response to the addition of copper as copper salts either as mineral supplements or through the addition of copper as fertilizer. This has been particularly true in Kentucky where young horses and cattle on these areas have shown some of the changes noted in cattle in the Everglades area of Florida. Response has been rapid, when a supplement of copper has been introduced. Critical evaluation has yet to be made, but the improvement in foal development has convinced thoroughbred owners that copper is necessary as a trace element. Deficiencies have not developed that are associated with interfering elements such as molybdenum, which in some areas causes deficiency symptoms to develop. In some of the alluvial soils of Louisiana and Mississippi, there have been observed changes suggestive of copper deficiency. Graying of the haircoat has been noticed in Louisiana and this has been attributed to a lack of copper or to abnormal copper relationships with other minor elements.

Molybdenum: Molybdenum toxicity problems have not been observed in the states indicated except in some parts of New

Jersey. In some alfalfa, abnormally high levels of molybdenum have been observed and associated with animal changes. In these areas, copper was at a low level, and symptoms similar to changes observed in the copper deficient soils of Florida were noted. That these conditions are not extensive may reflect the fact that the grazing season is short and, therefore, the animals have not developed the abnormal conditions before they are given supplements which correct largely some of the unbalanced mineral intakes.

Iron: Iron should be mentioned as a trace element that is involved in the nutrition of livestock.

In some parts of South Carolina, there are out-croppings in the coastal plain of iron-bearing rock and these have been known for many years as wild animal licks. Domestic cattle grazed in these same areas will use these out-croppings as licks, consuming the rock in appreciable amounts. The sodium chloride level is very low in these rocks. Iron is the principal trace element present, with a very small amount of copper.

It has been suggested that this is a sign of nutritional deficiency. The wild animals have been observed to use these only in the late summer or fall and the suggestion has been made that due to blood loss from insect attack during the summer, the demand for these minor elements is such as to lead them to make use of these out-croppings. This is an interesting speculation and perhaps some day a logical explanation will be obtained. At the present time, it can only be mentioned that this observation has been made and suggest that perhaps the animals do have a desire or a liking for the particular rock that appears in the otherwise sandy soils of this area.

In summary, it may be mentioned that cobalt deficiency has been observed in many of the states of the East and South of the U.S.A. and cobalt supplements in feed are common. Copper deficiency has been observed in at least five of the Southern states, including Florida. The deficiency has been less severe than has been observed in some parts of Florida, perhaps attributable to the lack of complicating factors such as the presence of molybdenum. Molybdenum has been found in some areas at levels higher than nutritionally desirable, but may be associated with continued fertilizer applications that have resulted in building up the molybdenum content of these soils to a point where legumes may contain amounts sufficient to interfere with animal nutrition if the copper intake is low.

WORK ON TRACE ELEMENTS IN ENGLAND, SCOTLAND AND IRELAND*

KATHERINE WARINGTON**

The earliest experiments on trace elements in Great Britain arose out of a bequest made in 1896 by Mr. E. H. Hills to the Royal Agricultural Society of England, for the purpose of determining the value of what he termed "the rarer forms of ash." Under this heading he included constituents such as fluorine, manganese, iodine, bromine, titanium and lithium. As a result, a series of pot culture experiments in soil was carried out by Voelcker at the Woburn Experimental Station, from 1897-1920, to test the possible benefit of these and other elements on wheat and barley (41). In some instances, provided only small quantities of the substance were used, a stimulating effect on the plant was obtained, but large doses invariably proved harmful. In 1910, at much the same time as French workers were obtaining beneficial results from the use of boron, manganese, and zinc compounds, (1, 2, 4, 5, 27) Brenchley began a series of investigations at Rothamsted on the action of arsenic, boron, copper, manganese and zinc on plants grown in nutrient solutions (8, 9). Though no evidence was forthcoming from her preliminary experiments that any of these elements were essential for growth, nevertheless a much better understanding of their mode of action was thereby obtained and interest in the possibilities of their practical application aroused. After a break of about ten years, work was resumed on the question, special attention being paid to the action of boron, and in 1923 Warington (46) obtained conclusive evidence that this element was essential for the normal development of at least certain of the higher plants. A series of investigations followed, each dealing with different aspects of the subject, with a view to determining the part played by boron in plant metabolism. This hope, however, was not realized, and in fact the question remains largely unsolved even today. At the same time, a good deal of light was thrown on the effects of a deficiency of the element on the plant. Perhaps the most important result was the discovery by Brenchley and Thornton (11) that boron was required for the proper development and functioning of the nodule in leguminous plants. In the absence of boron, the vascular supply to the nodule was found to be defective, while the bacteriod tissue, and in consequence the quantity of nitrogen fixed, was markedly reduced. From anatomical studies by Warington (47) and later by Rowe (38), it was clear that meristems were particularly dependent on a continual supply of boron, hypertrophy and break down of these tissues oc-

*—Presented by Dr. Roy A. Bain, Agronomist, Everglades Experiment Station, Belle Glade.

**—Plant Physiologist, Botany Department, Rothamsted Experimental Station, Harpenden, Herts., England.

curring in its absence. In the event of a renewal of the supply of boron, however, new and healthy meristems could develop (50), and Brenchley and Watson (14) obtained normal flowering in sugar beet plants which had suffered from severe heart rot in their first year of growth, following an application of boron in the second year, a finding of some practical importance to the seeds merchant. Among other results of these investigations, mention may be made of the indications of an association between boron and calcium nutrition obtained by Brenchley and Warington, (12, 48) which has since been confirmed and developed by various workers in other countries.

Boron deficiency diseases in the field, though frequently recorded in Great Britain for crops such as turnip, swede and sugar beet, have never attained a position of large-scale economic importance as they have in other parts of the world. Consequently the work on the practical side has not been very extensive.

Manganese deficiency, however, is of considerable importance in certain parts of England and much of the work with this element has been concerned with the practical aspects of the problem. In 1940, Wallace, of the Long Ashton Research Station, carried out a survey of soil types in England on which manganese deficiency had been reported for horticultural or agricultural crops (42). The trouble was found to be chiefly associated with the peaty soils of the Fen district, Romney Marsh in Kent and with areas in the West Midlands and Somerset, though it was liable to appear on newly ploughed up grassland and on reclaimed heaths. As has been found in other countries, the soils concerned were not necessarily low in total manganese, but invariably had a high organic matter content and a pH of 6.5 or more. Questions of availability were clearly involved, and from the work of Heintze and Mann at Rothamsted (22), it seems that under these conditions the manganese may become locked up in a non-available form as complexes with the organic matter in the soil. Other investigations by Dion in conjunction with these workers, have been concerned with the fractionation of various forms of manganese and manganese higher oxides in different types of soil (15). Crops vary widely in their demand for manganese. In cereals it is particularly high, though even in this group considerable varietal differences are exhibited, as Gallagher and Walsh (17) working in Ireland have found. Leguminous crops such as clover, on the other hand, generally have a low manganese requirement, but peas are very sensitive to any shortage, Heintze (20) in 1938 showing that marsh spot disease was due to a lack of manganese in the soil. The important part played by nitrogen in determining the incidence of marsh spot was evident from her later work (21), where she induced symptoms of the disease in peas grown on soils rich in available manganese, by injecting simple inorganic and organic nitrogen compounds into the plant. Healthy peas were found by Glasscock and Wain (18) at Wye

College to contain more manganese than those affected with marsh spot, but according to later work by Walsh and Cullinan (45), both healthy and diseased seeds in the same pod may have a very similar manganese content. With regard to remedial measures, spraying the plant with a solution containing manganese has been recommended both by Lewis (30) and Wallace and Ogilvie (44) in preference to soil applications. Correct timing of the treatment is important, and peas should not be sprayed before the flowering stage, if marsh spot is to be avoided.

Damage from excess manganese is uncommon in Great Britain, but the question has not been overlooked and both Wallace, Hewitt and Nicholas at Long Ashton (43), and Hale and Heintze (19) at Rothamsted have produced evidence of manganese toxicity in crops grown on acid soils.

Work on the function of manganese has been taken up comparatively recently in England. In 1948, Hewitt (24) made a study of the relationship between manganese and iron nutrition, showing that symptoms of iron deficiency induced by excess manganese or other heavy metals were not identical with those caused by a simple lack of iron. From this he concluded that the two elements have at least some independent functions in the plant metabolism. In conjunction with Jones and Williams (26), he was able to confirm the accumulation of nitrate in manganese and molybdenum deficient plants, and from a study of the amino-acid concentration in each case, to suggest that though the two elements are both required in the process of nitrate reduction, they probably function in different parts of the chain of reactions.

Some of the latest work with manganese has been on the biochemical side. Peroxidase preparations from horse-radish and turnip have been shown by Kenten and Mann (28, 29) at Rothamsted to oxidize manganous salts in the presence of certain phenolic substances and hydrogen peroxide. From their results, they put forward the hypothesis that the manganese reduced the oxidized peroxidase substrate, thereby becoming involved in an oxidation-reduction cycle, a theory which would be in keeping with the view that manganese plays a part in the processes of respiration.

Investigations on the effect of molybdenum on higher plants have been comparatively recent in Great Britain as elsewhere, though in 1934 Sheffield (39) had demonstrated cytological abnormalities in solanaceous plants treated with molybdates, while Warington (49) found that tannin-molybdenum compounds accounted for the yellow colouration in tubers of potatoes grown with excess molybdenum. Indications that the element was essential for lettuce were obtained in 1942-46 (13, 51) during the course of investigations at Rothamsted regarding the trace element constituents of Chilean nitrate, shortly after workers in other countries had proved that molybdenum was needed by tomato and oats (3, 34). More recently, Hewitt and Jones (25)

have made a special study of molybdenum deficiency effects on tomato and brassica crops, confirming the association of "whip-tail" disease of cauliflower with a lack of this element (Figures 1 & 2).

Results regarding the harmful action of excess molybdenum on plants have proved somewhat conflicting, and in a series of

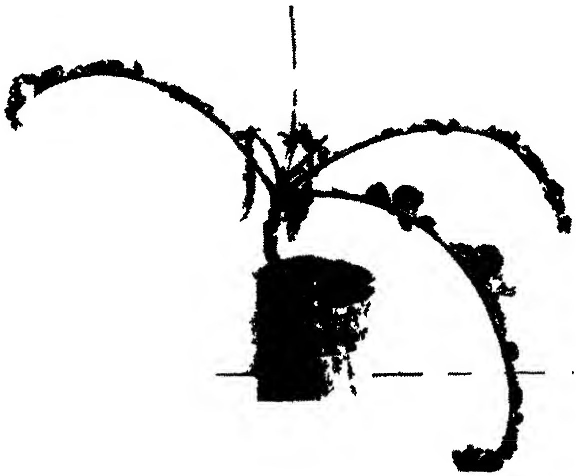

Figure 1.—Whiptail in Cauliflower grown in sand culture without molybdenum. E. J. Hewitt and E. W. Jones. Long Ashton Research Station.

Figure 2.—Molybdenum deficiency in Savoy Cabbage. L. Control. R. Without Mo. E. J. Hewitt and E. W. Jones. Long Ashton Research Station.

pot cultures in 1948, Brenchley (10) was able to show that the degree of toxicity depended both on the type of soil and the species of plant grown. For example, the harmful action of a specific dose of sodium molybdate was greater on a sandy soil compared with a black fen or clay soil (figures 3 & 4), but on the same soil, tomato might be uninjured by a dressing which

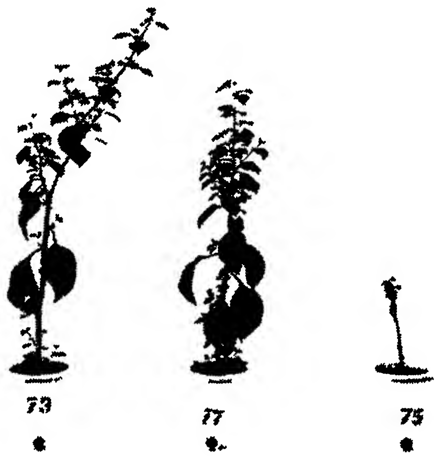

Figure 3.—*Solanum nodiflorum* in sandy soil. L-R. No Mo, Low Mo, High Mo. W. E. Brenchley. Rothamsted Experimental Station.

Figure 4.—Solanum nodiflorum in clay soil. L-R, No Mo, Low Mo, High Mo. W. E. Brenchley. Rothamsted Experimental Station.

was very poisonous to flax and fatal to *Solanum nodiflorum*. The fact that different plants may vary in molybdenum content when grown on the same soil has a practical bearing on the occurrence of "teart" in cattle, a disease due to molybdenum poisoning. Ferguson, Lewis, and Watson (16) at Jealott's Hill Research Station found, for example, that the risk was greatest when the proportion of clovers in the pasture was high, since legumes absorbed molybdenum more readily than grasses, and further, that the molybdenum content of herbage varied considerably with its stage of growth.

Instances of deficiencies of other trace elements have so far been isolated only, though benefit from zinc treatment has been reported for cherries by Thompson and Roberts (40) in 1945, and for cereals and potatoes by Roach and Barclay (37) in the following year. More recently Bould and others (6) described a failure of fruit trees due to a lack of zinc and have since found apples suffering from copper deficiency in the same district (7). A favourable effect from copper sprays has also been reported by Muskett (33) from Ireland. Such deficiency troubles, however, seem unlikely to become a large scale problem in Great Britain, though they will probably continue to arise in certain localized areas.

The correct diagnosis of symptoms of mineral deficiency or toxicity in a plant is naturally an essential before remedial measures can be applied. A valuable contribution to a better understanding of this aspect of the subject in the case of trace elements has been made at Long Ashton by Hewitt (23), who has developed a pot culture technique, using containers coated with bituminous paint and specially purified water, salts and sand. Under these controlled conditions, deficiency symptoms, of which the cause is known, can be produced in plants for comparison with field grown crops. Another method of approach has been adopted at East Malling Research Station. Here leaf analyses and response to leaf injection have been used by Roach (35) and others to diagnose any deficiency in the mineral status of the plant, and improved yields, based on the findings, obtained even when the crop failed to exhibit any visual symptoms of the trouble. The whole subject of injection has been studied in great detail by these workers, during the past ten years or so, one outcome of which has been the development of a technique suitable as a curative measure for fruit trees. Some of the most recent experiments by Roach (36) in 1947, however, emphasize the need for testing treatments based on any method of diagnosis with the subsequent performance of the crop, as in some cases the expected correlation was lacking.

All trace element studies call for specially refined analytical methods, both for purpose of rapid survey and exact quantitative measurement. Mitchell (31, 32), at the Macaulay Institute in Scotland, has worked out spectrographic techniques suitable for the geochemical study of rocks and the determination of trace

constituents in soil extracts and plant material, and it is now possible to estimate up to fifteen of these elements simultaneously.

The course of the investigations on the trace elements essential to higher plants seems to have followed a logical sequence, the first phases of which have been brought to a successful conclusion. Proof of the necessity of the elements has been obtained, the effect of their deficiency on various crops studied in some detail, and appropriate remedial measures developed. The most difficult stage has now been reached, namely that of determining the function or functions of the elements in plant metabolism. Mention has already been made of the probable part played by both manganese and molybdenum in nitrate reduction and the association of boron with calcium nutrition. It seems likely, however, that with the possible exception of boron, most of the essential trace elements will prove to be mainly concerned with enzymatic processes. Copper containing enzymes are already known, while zinc is thought to play a part in the activity of plant carbonic anhydrase. Future work may well show that manganese functions in some analagous manner. Many questions regarding availability of the elements to the plant remain unanswered, and in this field the help of the soil chemist will be needed. Fresh inter-relationships between the various elements are constantly being discovered, though their nature is not yet understood. The presence of cobalt in the soil, for example, apparently increases the uptake of molybdenum by the crop, while the addition of copper may produce symptoms of manganese deficiency in the plant. In addition, little is known of the part played by micro-organisms and developments in this field may be expected. The importance of the trace elements in plant life is now firmly established, but the co-operation of workers in many branches of research will be needed before their function is fully understood.

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INVESTIGATIONS ON TRACE ELEMENTS IN THE NETHERLANDS*

E. G. MULDER**

Introduction.

The beneficial effect of trace elements on plant growth in the Netherlands was shown for the first time by Sjollema and Hudig in experiments on a disease of oats on neutral and slightly alkaline peaty soils (14). Although in those days Hudig was of the opinion that this effect of manganese had to be attributed to the correction of some unfavourable condition of the organic matter, it was shown by further investigations that the oats disease was caused by lack of available manganese. Söhngen (16) and particularly Gerretsen (6) demonstrated the effect of microorganisms in rendering soluble manganese compounds in soil unavailable for the plants.

In 1924 it was found by Hudig and Meyer (7) that the so-called reclamation disease which was found on newly reclaimed peaty and sandy soils in the Netherlands may be cured by adding copper sulphate to the soil. In the same way as with manganese, the beneficial influence of the heavy metal was attributed to some mysterious effect on the soil organic matter. Other investigators were of the opinion that the disease was caused by microorganisms (2). Copper should have a disinfecting effect. After the discovery of the indispensability of copper for plant growth (Sommer (15), Brandenburg (3)), it was shown by the author (10) that the reclamation disease is caused by copper deficiency of the plants.

In 1933 Sjollema published a report on copper deficiency in cattle (licking disease) which was found in areas where the plants suffered from the reclamation disease (13).

In addition to manganese and copper a beneficial effect of iron, zinc, boron and molybdenum on plant growth has been found in the Netherlands.*** More details concerning these elements will be given below.

Occurrence of trace element deficiencies in the Netherlands.

Iron deficiency is found only sporadically in agricultural crops in the Netherlands. In horticulture this element is of more importance.

Manganese deficiency may be found on sandy and peaty soils

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***—Magnesium is not listed to the trace elements by the author. Therefore the investigations carried out on this element will not be recorded in this lecture.

where the reaction is approximately neutral. After the extensive investigations carried out by Dutch workers in the past, this fact is well-known by the farmers and therefore the reaction on this type of soil is maintained mostly between pH 5.0 and 5.6. At these values no manganese deficiency of the plants will be found.

On some clay soils containing a certain amount of organic matter and with a high content of calcium carbonate, where manganese deficiency also may be found, this adjustment of pH is not feasible. This is particularly the case on the light clay and sandy soils in the young polders of the Zuiderzee, which may contain more than 10 percent of calcium carbonate. Here applications of manganese salts have to be carried out every year. In some cases spraying of the crops with a 1.0-1.5 percent solution of manganese sulphate appeared to be more successful than application of the salt on the soil.

According to Gerretsen of this Experiment Station the insolubilization of manganese in neutral soils containing a certain amount of organic matter has to be attributed to the activity of microorganisms (6).

In liming experiments on a lowmoor peat containing a high amount of clay, carried out by the author, no manganese deficiency was observed within a period of 10 years after liming of the soil. It is unknown whether this result was due to the absence of manganese-oxidizing microorganisms or to the particular condition of the soil organic matter.

Zinc deficiency is found on apple, pear and cherry trees growing on soil very rich in phosphate (9).*

Copper deficiency (reclamation disease) may be found on sandy and peat soils, particularly shortly after reclamation of these soils. It is well-known by the farmers that under these circumstances they have to apply 50-100 kg of copper sulphate per ha. Therefore heavy symptoms of copper deficiency are found only sporadically in agricultural crops. A slight increase in yield after a copper dressing may be obtained rather frequently. More recently copper deficiency has been observed in orchards by Dr. D. Mulder, Laboratorium van Zeelands Proeftuin, Goes.

As to the occurrence of copper deficiency in animals the situation is more complicated. On soils poor in available copper, cattle may show symptoms of copper deficiency (licking disease). In some cases, however, a beneficial effect of feeding small amounts of copper to cattle has been observed notwithstanding the herbage which was fed had a normal copper content. This result is obtained particularly in the reclaimed North West polder of the Zuiderzee. Apparently uptake of copper from the food may be affected by some unknown factor. Although it is sometimes supposed that excess of molybdenum in the herbage may

*—Dr Gerretsen at this Station has worked out a micro-biological method to estimate available zinc in soil.

be the cause of the high copper requirement, more evidence is needed to confirm this hypothesis.

Boron deficiency may be found rather sporadically on sandy soils in the South of the country and on river-clay soils. Besides beets and turnips, leguminous crops may respond sometimes to small amounts of this element. In experiments with peas the author has shown that on boron deficient soils nitrogen fixation may be badly affected as a result of which the plants become deficient in nitrogen and die at an early date (11).

Recent investigations on trace elements carried out in the Netherlands.

During the last 15 years much work has been done by the author on the effect of copper and molybdenum on plant growth and on some physiological phenomena in both higher plants and microorganisms. These investigations started in 1935 when an extensive study was undertaken to elucidate the role of copper in preventing the socalled reclamation disease in plants. This disease which may occur on sandy and peaty soils particularly when they are newly reclaimed, occurs in many areas of Western Europe as well as in the U.S.A. and Australia.

To prove that the reclamation disease has to be attributed to a lack of plant-available copper the following three sets of experiments were undertaken.

a) *A comparison was made of the symptoms of copper deficiency in culture solutions with those of the reclamation disease.*

These symptoms appeared to be quite similar. This was not only true of the pronounced cases in which dead white tips occur at the youngest leaves of cereals and no ears emerge, but also of the light cases in which the ears emerge normally but the grain production is reduced. Plant species less susceptible to the reclamation disease (potatoes, rye) required less copper than highly susceptible plants like wheat, barley and oats. In addition the former have a greater absorption capacity for less available soil copper than the latter. This was concluded from the fact that the difference in copper requirement between both groups of plants growing in soil is much greater than when growing in nutrient solutions.

A crop very susceptible to copper deficiency is canary grass (*Phalaris canariensis*) which was successfully used by the author in pot tests as an indicator plant for copper deficiency.

When a comparison is made of the amounts of copper required for normal plant growth in nutrient solution and in peaty or sandy soil, it will be found that in the former case an amount of 50 γ* of copper per 2 l of nutrient solution, added only once, is enough to secure normal plant growth. When ap-

—γ = *gamma*, here and elsewhere below.

plied to the soil 5 mg. of copper per 2 kg of soil are required. This discrepancy is caused by the fixation of copper by soil organic matter. This was demonstrated by employing the root separation technique. One half of a cylinder was filled with "diseased" soil, the other half, separated by a glass plate, with quartz sand or with a nutrient solution. Plants were grown with part of their roots in the soil and the other part in the sand or the nutrient medium. When the copper was added to the nutrient-solution half, amounts similar to those required in the culture solution experiments were able to give normal plants. When added to the soil half, twenty times greater amounts of copper were unable to give normal plants.

b) *Copper determinations* were carried out in plants grown on normal and "diseased soils." In the latter case much lower copper values were obtained than in cereals grown on "healthy" soils.

c) *Plant available copper was determined in the soil by using a microbiological assay.* This method is based on the fact that the fungus *Aspergillus niger* requires small amounts of copper for the development of normal black spores. In a nutrient solution purified from copper this fungus develops a white sterile mycelium. With 0.2*r* of copper in 40 cc of nutrient solution yellow spores are formed, with 0.4*r* the colour of the spores is yellowish brown, with 1.0*r* grey-brown, with 1.5*r* grey-black, while 2.5*r* of available copper and higher amounts give black spores. For the estimation of available copper in soil one gram of air-dried soil is added to 40 cc of a purified nutrient solution in 1 l Erlenmeyer flasks. This medium is inoculated with a suspension of *Aspergillus* spores and after 4 days of incubation at 30° C the colour of the mycelia is compared with the colour scale of a set of standard cultures to which different amounts of copper have been added.

A great number of "diseased" and normal soils from different parts of the Netherlands were tested for available copper according to the above method. Part of the results is given in Table 1.

From these figures it will be seen that soils on which the plants show symptoms of the reclamation disease have a very low content of available copper. Soils on which the plant growth is normal have a considerable higher copper content.[r]

The results of these experiments clearly show that the reclamation disease is brought about by a lack of available copper in the soil.

[r]—The microbiological assay is employed by the Soil Testing Laboratory at Groningen to test soil samples for available copper. The method is modified by Dr. Gerretsen of this Experiment Station in order to be able to estimate amounts of available copper in the range — 15*r* per gram of soil. This is possible by doubling the concentration of nutrients in the solution.

TABLE 1.—PLANT GROWTH AND AVAILABLE-COPPER CONTENT

Soil	Plant growth	*Aspergillus*-available copper per 1 g of air-dried soil, r
Sandy soil	Normal wheat	> 2.5
Sandy soil	Normal white oats	> 2.5
Sandy soil	White oats, severely diseased	0.1
Sandy soil	White oats, moderately diseased	1.1
Sandy soil	White oats, normal	1.5
Sandy soil	White oats, normal	2.5
Sandy soil	White oats, diseased	0.3
Peaty soil	Wheat, severely diseased, rye normal	0.2
Sandy soil	Normal wheat	> 2.5
Sandy soil	Normal canary grass	> 2.5
Peaty soil	Normal wheat	> 2.5
Peaty soil	Normal wheat	> 2.5
Sandy soil	Normal wheat	2.5
Sandy soil	Wheat, slightly diseased	1.-
Sandy soil	White oats, normal	1.8
Sandy soil	White oats, diseased	0.4
Sandy soil	White oats, severely diseased	0.2
Peaty soil	White oats, severely diseased	0.1
Peaty soil	Wheat, slightly diseased	1.-
Sandy soil	White oats, severely diseased	0.25
Same field	Slightly diseased area	0.80
Same field	Normal area	1.70
Same field	Plants cured by copper sulfate	> 2.50
Peaty soil	Wheat, severely diseased	0.20
Same field	Normal area	2. -2.5

—r = gamma

The low content of available copper is often a result of the presence in the soil of black humus. This was shown in experiments with *Aspergillus niger* and also in percolation experiments. In the former copper sulfate was added in different amounts to the black humus from a healthy soil very poor in available copper. The mixture was incubated for 24 hours at room temperature, sterilized at 110° C for 10 minutes and thereafter added to a copper-free nutrient solution of *Aspergillus niger*. The following results were obtained.

	Fungus available copper
2 g black heath humus (total copper 2.6r)	0.2r
2 g black heath humus + 3r Cu, as sulphate, added	0.6r
2 g black heath humus + 5r Cu, as sulphate, added	0.8r
2 g black heath humus + 10r Cu, as sulphate, added	1.0r
2 g black heath humus + 20r Cu, as sulphate, added	2.0r

It will be seen that this black humus fixed added copper to a considerable degree.

In a subsequent experiment a sandy soil very poor in plant-available copper was percolated with a 0.25 percent copper sulphate solution for 8-10 hours with a speed of 100 cc per hour. Then the soil was washed with distilled water until a practically

negative reaction on copper by carbamate reagent was obtained. Subsequently the soil was percolated with a solution of 1 percent calcium nitrate until no more than 2r of copper per 10 cc of liquid was washed out. Then the exchanged and still bound copper were determined. The following figures were obtained:

	Exchanged by $Ca(NO_3)_2$ (per 1 g. of org. matter).	Retained in soil (per 1 g. of org. matter).
Soil with severe copper deficiency	46.7 mg Cu	24.3 mg Cu
Normal soil	37.8 mg Cu	5.1 mg Cu

These data show that in the copper-deficient soil the total amount of copper which can be retained after treatment with distilled water is considerably higher than in the normal soil. Of this copper 34 percent was not liberated after treatment with calcium nitrate. In the normal soil only 11.5 percent was retained after treatment with calcium nitrate.

In a subsequent experiment the same copper-deficient soil was compared with a peaty soil on which plants grew normally. In this case the total amount of copper which was retained by the copper-deficient soil after removal of the excess copper sulphate with distilled water was also nearly twice as high as the amount retained by the normal soil. Upon treatment with ½ N hydrochloric acid practically all of the copper was liberated from both soils.

Fixation of copper by hydrogen-sulphide producing bacteria.

In experiments with *Aspergillus niger* and cereals it was found that copper precipitated by hydrogen-sulphide forming bacteria was unavailable. Since copper precipitated chemically by hydrogen sulphide is readily absorbed by *Aspergillus* as well as by higher plants it must be assumed that the copper compound formed by the microorganisms is either copper sulphide, present inside the bacteria cell, so that it is protected from being oxidized, or is not copper sulphide.

In experiments with sterile cultures of barley and oats similar symptoms of copper deficiency were obtained as in solutions which were not sterilized.

Interaction of copper and other nutrients.

Copper-Manganese. Application of copper sulphate to copper-deficient soils sometimes may result in the appearance of manganese deficiency in the plants grown on these soils (8). Although the possibility that such soils are deficient in available manganese as well as in available copper may not be excluded, evidence is available that copper may catalyze the oxidation of

available manganese to less soluble compounds. Although it is unknown to what extent the insolubilization of manganese in soil has to be attributed to microbial activity, it is rather simple to demonstrate the oxidation of manganese compounds to manganic oxide by microorganisms (Gerretsen (6), Sohngen (16), Beyerinck (1). The author isolated a manganese-oxidizing fungus and studied the effect of copper on its capacity to oxidize manganous to manganic compounds. It appeared that traces of copper stimulated the formation of black manganic oxides to a considerable extent (10). Although it is unknown whether in copper-deficient soil a similar stimulation may occur after application of a copper salt, it is likely that under certain circumstances this may be true.

In an experiment with rye in nutrient solutions a clear effect of copper on manganese deficiency of the plants was observed. In this experiment copper was added in amounts of 0, 2, 10 and 50 γ per culture. When the plants were about one month old, heavy symptoms of manganese deficiency were observed in the solutions supplied with 50 γ of Cu. Those with 10 γ were free from manganese deficiency. Some vessels were supplied with 3 mg of $MnSO_4$; they recovered within a few days (Table 2). It is unknown whether in this experiment copper has stimulated the oxidation of manganese in the nutrient solution (the nutrient medium was not sterile) or that precipitation has taken place in the plant tissue.

TABLE 2.—EFFECT OF COPPER SUPPLY ON MANGANESE DEFICIENCY IN RYE.

Copper, γ/pot	0.2 mg $MnSO_4 . 4 H_2O$		3 mg $MnSO_4 . 4 H_2O$	
	Grain, g	Straw, g	Grain, g	Straw, g
0	0	1.17	0	0.61
2	0	3.18	0	5.08
10	0.2	9.06	1.04	6.43
50	0	1.18	0.15	5.03

In barley, oats and wheat no effect of copper on the manganese supply was observed.

Copper-Zinc, Copper-Iron.

In culture solution experiments with different amounts of copper, zinc and iron no interaction between copper and zinc and copper and iron was observed (barley).

Copper-Cadmium.

In experiments with *Aspergillis niger* a clear interaction of cadmium and copper was observed. With increased amounts of cadmium more copper had to be supplied to induce black spores (Table 3). In barley no effect was observed.

TABLE 3.—EFFECT OF CADMIUM SULPHATE ON COLOUR OF ASPERGILLUS SPORES SUPPLIED WITH DIFFERENT AMOUNTS OF COPPER.

$3\,CdSO_4 \cdot 8\,H_2O$ γ	No copper supplied	2γ Cu	6γ Cu	20γ Cu
0	bright yellow	black	black	black
25	bright yellow	black	black	black
50	bright yellow	brown-black	black	black
100	bright yellow	brown-black	black	black
200	no spores	gray-brown	brown-black	black
500	no spores	yellow	brown-black	brown-black
1000	no spores	yellow	brown	brown-black
2000	no spores	yellow	yellow-brown	brown

Copper-Nitrogen.

In pot experiments with wheat growing in a copper-deficient soil supplied with different amounts of copper and nitrogen (as ammonium nitrate), an interaction between copper and nitrogen was observed. In the absence of supplied nitrogen and copper, small but entirely normal plants developed which were able to produce normal seeds. Supplied with a small amount of nitrogen, heavy symptoms of copper deficiency appeared and no grains were produced. As will be seen from Fig. 1, increasing amounts of added ammonium nitrate required increasing amounts of copper to obtain normal plants.

Physiological effect of copper.

Copper plays a role as the prosthetic group of oxidizing enzymes (tyrosinase, laccase, ascorbinase etc.). Apparently due to this function the effect of copper on a number of oxydation reactions, studied by the author, may be explained. These reactions are: a) blackening of *Aspergillus niger* spores, b) blackening of aging cultures of *Azotobacter chroococcum,* c) oxidation of manganous compounds to manganic oxid by fungi, d) transformation of aethyl alcohol to acetic acid by *Acetobacter aceti* (10).

More recently the effect of copper on tyrosinase activity in potato tubers was investigated in the author's laboratory. In an extensive study on the blackening of potassium-deficient potato tubers it was found that this phenomenon is due to the oxidation of tyrosine to red and then black oxidation products by tyrosinase. This reaction can proceed only when the cells are injured, so that tyrosine is subjected to tyrosinase activity. Potassium-deficient tubers are much more liable to injury than those with a normal potassium supply. In addition their tyrosine content is much higher (12). Both factors are responsible for the blackening.

When potatoes are cultivated on soils poor in available copper and poor in available potassium, blackening of bruised tubers

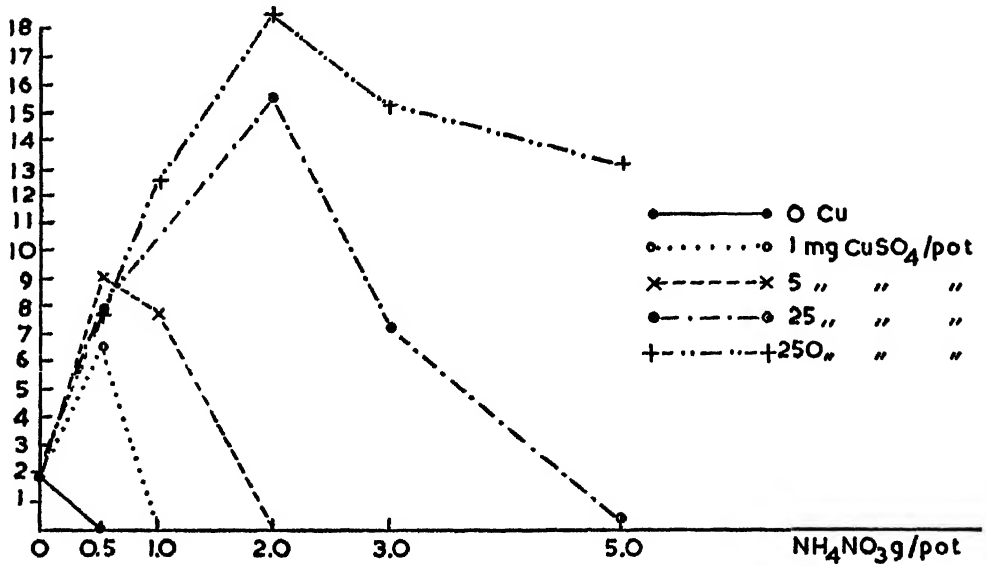

Figure 1.—Interaction of copper and nitrogen (Pot experiment with wheat) Yield on ordinate is grams grain per pot.

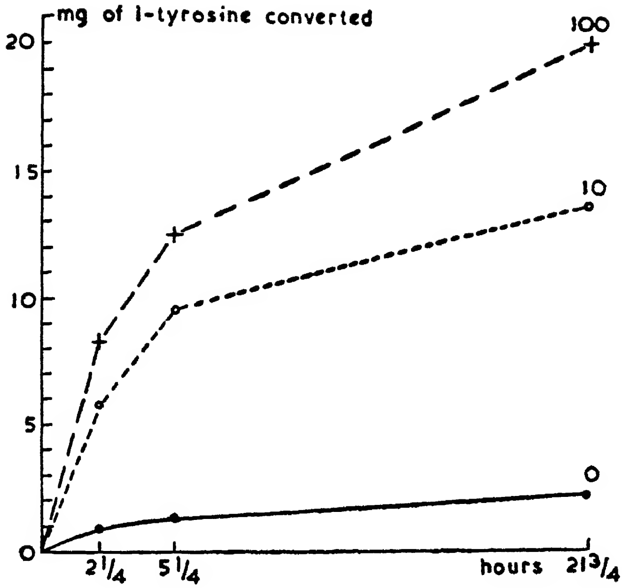

Figure 2.—Effect of the supply of copper to potatoes on the tyrosinase activity in the tubers. On the Chart:
0 no copper supplied
10 copper sulfate, 10 kg./ha.
100 copper sulfate, 100 kg./ha.

occurs only to a small extent. This is due to the low tyrosinase activity of potatoes poor in copper (Fig. 2).

The question may be put whether or not tyrosinase plays the part of a terminal oxidase in the respiration of potato tubers. Although some authors are of the opinion that this is true, little evidence can be found in literature.

In the author's experiments no difference in respiration rate of copper-deficient and normal tubers was observed. Infiltration of tuber slices with the copper reagent diaethyl-dithio-carbamate gave a considerable decrease of carbon dioxide output, however, indicating that copper may be of considerable interest in respiration. These investigations are being continued.

Effect of molybdenum on plant growth and nitrogen metabolism of plants and microorganisms.

A second trace element which has been studied extensively by the author in the last few years is molybdenum. In comparison with copper it is required by higher plants and microorganisms in considerably lower amounts.

Some years ago the effect of molybdenum on growth and nitrogen metabolism of a number of higher plants and micro-

organisms was studied. From these investigations which are published in Plant and Soil 1, 94, 1948, the following conclusions may be drawn:

a) Molybdenum is an *essential element* for the normal development of green plants and a number of microorganisms.

b) In the green plant as well as in the cells of bacteria and fungi, molybdenum is required for the *assimilation of nitrate* nitrogen. This was shown in experiments with tomato and barley plants and with denitrifying bacteria and the fungus *Aspergillus niger*.

c) Molybdenum is essential for the *fixation of nitrogen* by free-living bacteria as well as by symbiotic bacteria (*Rhizobium*). In experiments with peas many nodules developed on the roots in nutrient solution without supplied molybdenum but the nitrogen fixation of these nodules was insignificant so that the plants became nitrogen-deficient and died at an early stage.

Experiments with soil.

In order to investigate whether or not molybdenum deficiency might occur in Dutch soils, pot and field experiments were carried with peas on soils where the pea growth was poor. No effect of molybdenum application was observed so that it was concluded that molybdenum deficiency did not occur in the Netherlands.

After the war some pot experiments were carried out with molybdenum-deficient soil received from Australia by courtesy of Professor Prescott, Waite Institute, Adelaide. A clear response to molybdenum was found in white clover and subterranean clover but not in pea (Table 4). Since the Australian soils used in these experiments were rich in ironstone and rather acid, pot experiments were undertaken with an acid lowmoor peat soil, rich in ironstone, from the province of Groningen (organic matter 60 percent, pH 5.0).

TABLE 4.—EFFECT OF MOLYBDENUM ON YIELD AND NITROGEN FIXATION OF CLOVER, GROWN IN AUSTRALIAN SOILS.

Soil received from	pH	$Na_2MoO_4 . 2\,H_2O$ per pot (2 kg soil) mg.	White clover Yield, g Dry-wt.	White clover Nitrogen mg.	Subterranean clover Yield, g Dry-wt.	Subterranean clover Nitrogen mg.
Tasmania	6.2	0	4.2	110.5	12.9	272.0
Tasmania	6.2	5	12.2	382.0	16.8	428.5
S. Australia	5.4	0	4.3	93.4	11.1	243.0
S. Australia	5.4	5	5.9	170.0	17.3	395.0

In agreement with the results obtained with the Australian soils a big response to molybdenum was observed in white and red clover. Without application of molybdenum many nodules had developed in both plant species. These nodules were smaller

than those of plants supplied with molybdenum, whereas the colour was not pinkish as usual but yellow or brown-gray. Nitrogen fixation was quite inadequate, as a result of which the plants became pale green and grew much poorer than those supplied with traces of molybdenum. With improved molybdenum supply the number of nodules decreased but their nitrogen fixing capacity increased considerably (Table 5).

TABLE 5.—EFFECT OF APPLICATIONS OF MOLYBDENUM ON NITROGEN FIXATION AND YIELD OF WHITE CLOVER GROWN ON AN ACID LOWMOOR PEAT SOIL RICH IN IRONSTONE.

$Na_2MoO_4 . 2\,H_2O$ applied per pot† γ	Dry weight g. per pot	Nitrogen in plants, per pot, mg.	Number of nodules per 173 cm^2 bottom of glass cylinder	Molybdenum in plants mg. per kg of dry matter
0	2.1	51.6	456	< 1
10	2.7	71.7	368	1.8
50	4.1	131.0	254	2.4
100	4.7	152.0	151	3.7
500	4.8	158.7	87	4.3
1000	4.8	155.0	116	3.3
2500	4.7	150.0	123	6.5
5000	4.6	147.9	116	13.7
10000	4.8	151.0	107	25.4
20000	3.8	127.0	109	80.0
50000	4.4	147.0	70	183.1

†—Each pot contained about 500 g of soil.
—Averages of duplicate values

As will be seen from these results, optimal nitrogen fixation of white clover was attained already at 100 γ $Na_2MoO_4 . 2\,H_2O$ per pot (about 200 g per ha). With higher rates, nitrogen fixation was only slightly changed. The molybdenum content of the plant tissue rose considerably, however. Since it is a well-known fact that a molybdenum content of the herbage of 20 mg per kg of dry matter may cause cattle-poisoning, care should be taken that these values will not be reached.

With red clover similar results were obtained. Peas and beans did not respond to molybdenum.

In a subsequent pot experiment with 33 soils from different parts of the Netherlands the response of white clover to molybdenum was studied. These soils were mostly rich in iron. On about 20 of these soils big responses to molybdenum were obtained. Amongst the latter soils there were two clay soils.

In another experiment responses to molybdenum in white clover were observed on acid sandy soils with pH-values varying

from 4.2-4.9. The difficulty here was that independently of molybdenum supply, nodulation was much depressed by an acid soil reaction. Once nodules had developed, a clear stimulation of nitrogen fixation was observed when molybdenum had been supplied to the plants.

From these results it may be concluded that molybdenum deficiency is of much more general importance in the Netherlands than was originally believed. No doubt in other countries of Western Europe and perhaps in the U.S.A. similar results may be found. Further research is in progress to study the effect of molybdenum on white clover under field conditions and to see whether other leguminous crops, particularly alfalfa, respond to molybdenum similarly to white clover.

Another problem which is being studied by the author is the interaction copper-molybdenum. It is a well-known fact that on pastures high in molybdenum cattle will be poisoned by a high molybdenum content in the herbage (teart pastures of Somerset (5)). Under such circumstances copper shows a beneficial effect on the health of the cattle. Burema and Wieringa (4) described an interaction between copper and molybdenum in *Azotobacter* some years ago. Although in nitrogen fixing white clover in some cases a clear effect of copper on molybdenum supply has been observed by the author, more research has to be done before conclusions can be drawn.

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COPPER, ZINC, MANGANESE AND MOLYBDENUM DEFICIENCIES IN AUSTRALIA[*]

D. S. RICEMAN[**]

The aim of this review is to bring before you the circumstances under which trace element deficiencies occur in plants in Australia, and to describe the progress we have made in investigating the problems involved. No reference is made to research done overseas in this field, but that does not imply an ignorance or a lack of appreciation of it.

Deficiencies of one or more of the elements copper, zinc, molybdenum and manganese are those most important to agriculture in Australia. Corrective treatments are applied to sown pastures and small grain crops over very extensive areas, and commonly to fruit trees and vegetable crops. Moreover, we have discovered the occurrence of various trace element deficiencies, chiefly zinc and copper, in much of the undeveloped country in our higher-rainfall areas. Grain crops and pastures are now being sown in these lands, which were formerly considered useless.

The most common occurrence of these deficiencies is in southern Australia, in regions of winter rainfall and summer drought, where the rainfall exceeds about sixteen inches per annum; or more precisely, south-western Western Australia, south-eastern South Australia, southern Victoria, Tasmania and south-eastern New South Wales. Many thousands of square miles are involved in all, but lest I mislead you I must point out that the country affected in this way represents but a fraction of the total of our agricultural lands.

Certain deficiency diseases of ruminant animals are also of comparatively frequent occurrence. Among them are "enzootic marasmus," a fatal wasting disease of sheep, caused by cobalt deficiency; "enzootic ataxia" of lambs and "falling disease" of cattle, both caused by copper deficiency; and "coast disease" of sheep, caused by a dual deficiency of cobalt and copper. These diseases are restricted largely to southern Australia. On the other hand, "straight steely" wool, which is a manifestation of mild copper deficiency in sheep, has been observed in every State in the Commonwealth.

The research into the cause of these animal diseases renewed our interest in the deficiency diseases of plants. That "grey speck" disease of oats was manganese deficiency disease had long been known, and it had been a common practice to apply copper to fruit trees for the correction of certain disorders.

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Once copper deficiency was known to be involved in "coast disease" in sheep, however, it was a simple matter to apply the discovery to certain problems involving the growth of pastures and cereal crops in the "coasty" areas. Such promising results were obtained that the research was directed to similar problems in other soils, and there soon followed the discovery of a deficiency of zinc, and later molybdenum, in crops and pastures in many of the agricultural areas.

An excellent account of the main climatic features of Australia and the soil zones that are recognized, is to be found in a well-illustrated handbook entitled "The Australian Environment." This deals briefly with many topics relating to Australian agriculture (C.S.I.R.O. 1949).

Manganese

Manganese deficiency occurs in cereals in South Australia[1] in cereals and occasionally in vegetable crops in Western Australia[2] and in citrus in coastal New South Wales[3]. There is some indication also that additions of manganese, as well as zinc and copper, may benefit certain legumes in recently reclaimed areas of calcareous peat in South Australia (Anderson 1946b). These occurrences of manganese deficiency are restricted to comparatively small and rather well-defined areas, but usually the crops raised are affected seriously unless corrective measures are taken.

The discovery that "grey speck" or "road take-all" of oats was a manganese deficiency disease enabled Samuel & Piper (1928, 1929) to establish the fact that manganese is essential for plant growth. Piper (1941) later showed that a condition in peas, known as "marsh spot," is due to a partial deficiency of manganese.

Very considerable differences in the susceptibility of various crops to manganese deficiency have been demonstrated in the field and in water-culture. Of the cereals, oats is the most susceptible (Samuel & Piper 1928, 1929; Leeper 1941). Subterranean clover and peas may remain unaffected in soil that produces manganese deficiency in wheat (Adams 1937; Leeper 1947), and many pasture plants and some weeds have been observed to grow well in soils that will not grow healthy oats (Samuel & Piper 1929; Leeper 1935a). There is evidence also of variability among the pasture plants themselves (Anderson 1946b).

The soils that produce crops deficient in manganese are not themselves deficient in that element[4]. The chemistry of man-

1—Samuel & Piper (1928); Piper (1931); Scott (1932).
2—Carne (1927); Teakle, Hoare & Thomas (1933); Wild (1934); Adams (1937); Teakle (1939 and 1945); Teakle & Morgan (1939); Teakle & Wild (1940); Teakle, Morgan & Turton (1941); Teakle & Turton (1943).
3—Levitt & Nicholson (1941); Benton (1942).
4—Samuel & Piper (1928); Piper (1931); Leeper (1935a).

ganese in the soil and the factors concerned with its availability are therefore very important, and have received much attention.[5] Control methods that are adopted, however, are confined to applications of manganese as a fertilizer and to cultivation of less susceptible crops.[6]

In oats, the concentration of manganese is highest during the early growth stages. There is not a marked fall as the plants mature, and during grain formation most of the manganese remains in the straw (Piper & Walkley, 1943). It will be seen later that this differs from the behaviour of zinc and copper under the same conditions. Plants showing evidence of manganese deficiency are found to contain much less manganese than healthy plants (Samuel & Piper 1928, 1929), and one of the consequences of the deficiency is an accumulation of nitrate in the tissues (Leeper, 1941).

COPPER

Copper deficiency in plants is of such widespread occurrence in south-eastern South Australia and south-western Western Australia that it is not possible in a review of this nature to describe the areas and the soils concerned. In general, the deficiency is most common in the sandy and gravelly types, and it is there quite frequently associated with zinc deficiency. On geochemical evidence this is not surprising (Thomas 1938, 1940). Many of these soils are aeolian in origin and have been derived in geologically recent times from calcareous sands (Crocker 1946). It is in areas of the calcareous sands as they exist today that cobalt and copper deficiency in ruminant animals (Marston et al, 1938; Marston, Lee & McDonald 1948a, 1948b; Marston and Lee 1948a, 1948b) and copper deficiency in plants (Riceman & Donald 1938; Riceman, Donald & Evans 1940; Piper 1938) are exhibited in their most acute forms. Zinc deficiency has also been observed there, under certain conditions (Riceman & Anderson 1941; Riceman, unpublished data). Copper deficiency has been observed in other soils, including peats, rendzinas and terra rossas. Over all types the range of soil pH extends from strongly acid to highly alkaline.

The deficiency is of most common occurrence in cereal crops and pasture plants, particularly the pasture legumes[7]. Vege-

5—Samuel & Piper (1928, 1929); Piper (1931); Leeper (1934, 1935a, 1935b, 1940, 1947); Leeper & Swaby (1940).

6—Samuel & Piper (1928); Scott (1932); Wild (1934); Adams (1937); Teakle & Morgan (1939); Teakle & Wild (1940).

7—Piper (1938); Riceman & Donald (1938); Riceman, Donald and Evans (1940); Riceman & Anderson (1943a); Riceman (1945, 1948a); Stewart & Teakle (1939); Teakle & Morgan (1939); Teakle, Turton & Throssell (1940); Teakle, Thomas & Turton (1941); Teakle (1942b, 1943); Teakle & Turton (1943); Beck (1941); Bennetts et al (1941); Strong (1941); Underwood & Beck (1941); Wild & Teakle (1941); Bennetts & Beck (1942); Lee & Riceman (unpublished report, 1943);

table crops are affected in localized areas, mostly in Western Australia, and there are records of the deficiency occurring in fruit trees in some of the fruit-growing areas[8]

In many localities where sheep produce "steely" wool there are no visible signs of copper deficiency in the plants constituting the deficient diet. This may be a matter of species resistance, but it suggests that copper deficiency could become a limiting factor for other species of plants which might be introduced into those areas.

Fortunately, the prevention or control of copper deficiency in field crops and pastures is usually a simple matter. Most arable soils in southern Australia are deficient in phosphate, necessitating annual applications of superphosphate. Copper sulphate is incorporated in this fertilizer, as required, and is thus distributed with it at little additional cost.

Usually a single application of about 7 lb. of copper sulphate per acre brings about complete control of copper deficiency in both crops and pastures.[9] Corrective dressings do not have to be applied annually. In fact, a single light dressing of copper sulphate will prevent the recurrence of copper deficiency in the crops and pastures for many years, even where the deficiency has occurred in its most acute form.[10] As little as 7 lb. of copper sulphate per acre is excessive on some of the sandy soils, and 2 lb. or 3 lb. per acre have proved satisfactory under those conditions (Teakle 1942a; Wild & Teakle 1942; Northcote & Tucker 1948).

Copper deficiency in one of the calcareous sands is extremely acute (Riceman & Donald 1938; Riceman et al 1940; Piper 1938). Copper sulphate applied to that soil at seeding will enable the cereals to produce grain. A further and even a more striking improvement in the crop can be obtained, however, by applying the copper dressing several months before seeding is commenced (Riceman 1946). It appears that the application of copper to this particular soil not only corrects the copper deficiency, but also increases the supply of available nitrogen from the accumulated plant residues and increases the supply of available zinc. In this a time factor is evidently involved, which would also account for the transient nature of the responses observed after applications of zinc to this particular soil (Riceman, unpublished data). In Australian experience this is an exceptional case, al-

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Underwood et al (1943); Jones & Elliott (1944); Anderson (1946b); Trumble & Ferres (1946); Bennetts, Beck & Harley (1948); Trumble (1949); Waite Institute Report (1950).

8—McCleery (1929); Pittman (1935, 1936); Dunne (1938, 1946); Teakle & Morgan (1939); Teakle, Morgan & Turton (1941); Teakle, Johns and Turton (1943); Teakle & Morgan (1943); Ward (1946).

9—Riceman, Donald & Evans (1940); Riceman & Anderson (1943a); Riceman (1945, 1948a); Teakle, Morgan & Turton (1941); Teakle (1942a); Piper (1942); Wild & Teakle (1942); Jones & Elliott (1944).

10—Riceman & Anderson (1943a); Riceman (1948a, 1948b, 1948c); Jones & Elliott (1944); Dunne (1948); Northcote & Tucker (1948).

though it is seemingly not without parallel in other countries. An increase in activity of the soil microorganisms when the copper deficiency is corrected may account for the observed phenomena. This has yet to be proved.

Much attention has been paid to studies of the copper content of plants, chiefly for purposes of diagnosing or confirming the possible occurrence of copper deficiency in crops, pastures and stock. It has become evident that the assimilation of copper is governed to a greater extent by species than by the soils in which they are grown (Riceman, Donald & Evans 1940; Teakle, Thomas & Turton 1941; Piper & Walkley 1943; Moore 1950).

The copper content of cereals is highest during the early growth stages, and declines with increasing age of the plant (Beck 1941; Piper 1942; Piper and Walkley 1943). Applications of copper to the soil bring about very little, if any, increase in the copper content of these plants, even under conditions where copper deficiency is known to be acute (Teakle, Turton & Throssell 1940; Riceman, Donald & Evans 1940; Teakle, Thomas & Turton 1941; Piper 1942; Teakle & Turton 1943). The same is true in respect to potato and tomato plants (Teakle, Morgan & Turton 1941).

Visible symptoms of copper deficiency in wheat, barley and oats are well-defined, particularly so in oats (Piper 1938, 1942; Riceman & Donald 1938; Riceman, Donald & Evans 1940; Riceman & Anderson 1943b; Wild & Teakle 1942; Millikan 1944; Dunne & Throssell 1948). This is fortunate, because a determination of the copper content, except perhaps at the seedling stage, is of little value for diagnostic purposes (Wild & Teakle 1942; Teakle & Turton 1943; Dunne 1948).

Lucerne, subterranean clover and other legumes, however, can accummulate comparatively large amounts of copper, and the concentration varies considerably according to the soil in which the plants are grown. An application of copper to the soil usually brings about an appreciable increase in the copper content of these legumes (Riceman et al 1940; Teakle, Thomas & Turton 1941; Piper 1942; Teakle & Turton 1943). Analysis of leaf and petiole material has been found to provide useful information in regard to the well-being, not only of the plants themselves, but also of the animals grazing them (Beck 1941; Teakle, Thomas & Turton 1941; Wild & Teakle 1942; Teakle & Turton 1943). This again is fortunate, for it is uncommon to find any visible symptoms of copper deficiency in these species in the field, other than reduced growth and poor seed production (Riceman, Donald & Evans 1940; Riceman 1948a; Strong 1941; Piper 1942; Jones & Elliott 1944).

It would appear that developing floral organs of oats have a higher copper requirement than developing leaves. Comparatively mild copper deficiency leads to death of the flowers during the early stages of development (Wood & Womersley 1946), and in this way inhibits grain production while not causing any

serious hindrance to vegetative growth. In fact, continued vegetative growth, in the form of new tillers, is a characteristic feature of copper-deficient oats (Riceman et all 1940, 1943b; Piper 1942). It is for this reason that a crop already affected by copper deficiency can be made to produce grain even though the application of copper is delayed until quite late in the season (Riceman et al 1940, 1943a; Piper 1042).

In subterranean clover (Riceman 1945, 1948a; Jones & Elliot 1944), in peas (Riceman et al 1938, 1943b; Strong 1941; Teakle, Morgan & Turton 1941; Piper 1942), and in other crops too, a lowered seed production reflects an incipient copper deficiency where vegetative growth is not seriously curtailed.

Approximately half of the copper in maturing oat plants finds its way into the grain (Piper & Walkley 1943), but the immediate source of this copper has not been determined. It is thought that the leaves make no contribution, as there is evidence that all the copper reaching them is immobilized (Wood & Womersley 1946). Continued absorption is not vital to flowering and seed production, because plants grown for only 14 days in water-cultures containing adequate copper and then transferred to cultures that are copper-free, will grow to maturity and produce grain (Piper 1942). There is clearly a need for further research into the distribution of copper among the various parts of the plant, and into the factors concerned with its translocation, particularly translocation into the developing inflorescences.

Wherever copper deficiency has been observed there are records of species and varieties that survive and even flourish in the deficient terrain. A few instances of this so-called "resistance" will serve to show that Australia is no exception.

In certain areas in Western Australia, drooping-flowered clover (*Trifolium cernuum*), fog grass (*Holcus lanatus*) and *Lotus major* persist where subterranean clover fails on account of copper deficiency (Teakle & Morgan 1939; Beck 1941; Jones & Elliott 1944). In South Australia, large tracts of calcareous sand are colonized by two poor-quality grasses (*Bromus madritensis* and *Lagurus ovatus*) and occasionally by the native legume *Swainsona lessertiifolia*. These species grow vigorously and produce a mass of seed, while many cultivated plants will not even survive in that soil unless additional copper is provided (Riceman et al 1938, 1940). Rye corn is a "resistant" crop which can be grown in copper-deficient soils (Riceman et al 1938, 1940; Teakle & Morgan 1939; Piper 1942). Rotenburger black oats and *Avena strigosa*, two varieties introduced from Europe for experimental purposes because of their reported "resistance" to copper deficiency, have flourished where the cultivated varieties of oats will produce but little grain or none at all (Riceman et al 1940, 1943b). These are all striking examples, but less obvious cases of "resistance" or "susceptibility" are equally common (Teakle & Morgan 1939; Teakle,

Morgan & Turton 1941; Riceman 1945, 1948a; Anderson 1946b). Their occurrence intensifies the need for a better understanding of the processes of absorption and utilization of copper.

In Western Australia and South Australia good correlation has been obtained between the copper content of pastures and the observed occurrence in ruminant animals of various manifestations of copper deficiency, such as "ataxia" in lambs and "falling disease" in cattle (Beck 1941; Underwood & Beck 1941; Bennetts et al 1941; Bennetts & Beck 1942; Bennetts, Beck & Harley 1948; Marston & Lee 1948b and unpublished data; Lee 1949). However, it is only after detailed studies of this sort have been carried out in the regions concerned, that the copper content of the pasture can be related, with any certainty, to its ability to maintain stock in good health. Due consideration must be given to the influence of growth stage, botanical composition and the extent to which the pasture has been grazed (Beck 1941; Marston & Lee 1948b). Even then there are a number of more elusive factors that can invalidate the conclusions. Among these are seasonal conditions (Lee 1949), exemplified by the rate of growth of the plants, and possibly the molybdenum content of the herbage (Marston & Lee 1948b and unpublished data; Marston 1949; Bull 1949), which itself varies independently of the copper content (Piper & Beckwith 1949; Moore 1950).

ZINC

Zinc deficiency has been observed in pastures[11] and cereal crops[12] in Western Australia, South Australia and Victoria. It is most common, but by no means universal, in soils of light texture, and in those soils it is often associated with copper deficiency. Zinc deficiency has also been observed in flax in very restricted areas of heavy soil (Adam & Piper 1944; Millikan 1946, 1947a; Cass Smith & Harvey 1948).

In Western Australia and in South Australia a disorder known as "rosetting" occurs in pine trees in sandy soil (Kessell & Stoate 1938; Teakle 1939; Teakle & Turton 1943; Stephens et al 1941; Northcote & Tucker 1948). In all States there are records of either "little-leaf" in deciduous fruit trees (Morwood 1937; Ward 1939, 1944; Anon. 1944; Kemp & Beare 1944; Kemp 1946; Walsh 1948; Wade 1949b; Gayford 1949) or "mottle-leaf" in citrus (Pittman & Owen 1936; Benton 1937, 1942; Strickland 1937; West 1938; Teakle 1939; Anon. 1943, 1944; Gayford 1947). All three disorders are the result of zinc deficiency.

11—Riceman & Anderson (1941, 1943a); Riceman & Powrie (1948); Riceman (1945, 1948a, 1950); Ferres & Trumble (1943); Teakle & Turton (1943); Anderson (1946); Trumble & Ferres (1946); Waite Institute Report (1950).

12—Millikan (1938, 1940, 1941); Foister & Hore (1939); Riceman & Anderson (1941, 1943a); Riceman (1945, 1946); Dunne & Throssell (1948); Dunne, Smith & Cariss (1949); Anon. (1949a).

By means of water-cultures it has been possible to produce well-defined symptoms of zinc deficiency in cereals (Piper 1940b; Millikan 1942) and in flax (Millikan 1942). In field grown cereals, however, the symptoms are not always well-defined, even where the deficiency is comparatively acute (Millikan 1938, 1942; Forster & Hore 1939; Riceman & Anderson 1843b; Dunne & Throssell 1948). On the other hand, oats grown in recently cleared sandy soil commonly develop a striking bronze discolouration, particularly in the lowest leaves (Riceman 1945; Dunne, Smith & Cariss 1949). Such a pronounced discolouration is not one of the accepted symptoms of zinc deficiency and may be due to complications involving phosphorus. It is corrected by an application of zinc sulphate which also increases the grain yield considerably.

The productiveness of subterranean clover, which is the legume most commonly employed in pastures in these light soils, can often be increased strikingly by an application of zinc sulphate. In these situations it is usually necessary to apply copper as well, to improve the production of seed (Riceman 1945, 1948a). The appearance of the plants may give no indication at all of zinc deficiency, except in relatively acute cases, when dwarfing and yellowing of the leaves and failure of the stems to elongate provide unmistakable evidence of zinc deficiency (Ferres, personal communication; Powrie & Riceman, unpublished data).

Trial and error methods in the field, using appropriate fertilizers, are thus still indispensable in determining the need for applications of zinc where the deficiency is suspected. Similar methods, carried out in small pots of the suspected soils in the glasshouse, prove a useful subsidiary to investigations in the field (Ferres & Trumble 1943).

Some progress has been made in efforts to recognize incipient zinc deficiency in subterranean clover by means of plant analysis. Legumes accumulate more zinc than grasses grown in the same soil (Piper & Walkley 1943), and their zinc content varies widely according to growth stage, soil, and fertilizer treatment (Teakle & Turton 1943; Riceman, Powrie & Jones, unpublished data). The determination of the zinc content of leaf and petiole material of subterranean clover, collected at the time of flowering, seems to show promise of revealing incipient zinc deficiency in these plants (Teakle & Turton 1943; Riceman, Powrie & Jones, unpublished data). However, such data must still be interpreted with reserve because light duration, air temperature, and other environmental factors can influence the uptake of zinc and its distribution within the plant, often with far-reaching consequences (Trumble & Ferres 1946; Ferres 1949).

Some attention has been paid to the distribution of zinc in oats and to the effects of inadequate absorption, but similar studies in subterranean clover have been sadly neglected.

In oats the concentration of zinc is highest during the seedling stages (Piper & Walkley 1943) but absorption continues throughout the growing period (Sibly 1949). At maturity, about three-quarters of the zinc in the above-ground parts of the plant is concentrated in the grain (Piper & Walkley loc. cit.). It appears that the leaves do not contribute to this concentration, as all the zinc reaching the leaves is retained permanently by them, even under conditions of zinc deficiency (Sibly loc. cit.).

There is some evidence that zinc is involved in phosphorus metabolism (Quinlan Watson, private communication), in protein synthesis (Sibly 1949) and in the rate of photosynthesis (Ferres 1949), of plants.

In preliminary investigations into the relation of zinc to phosphorus metabolism, zinc-deficient oats in water-cultures were found to contain extremely large amounts of phosphorus, of which an abnormally large proportion was in the inorganic form (Quinlan Watson, private communication). The ratio of P to Zn, at the late tillering stage, was not below 1000:1 and in some cases it greatly exceeded that figure. The ratio in zinc-treated plants was of the order of 300:1. A ratio of 100:1 (P_2O_5/Zn ratio of 230) has been observed at maturity in wheat grown on fertile soil (Walkley 1940). Further research in this direction is justified on practical as well as on theoretical grounds. If an abnormal accumulation of phosphorus proves to be a general consequence of zinc deficiency, the ratio of P to Zn would give a clear indication of deranged metabolism. This ratio, by varying more widely than the simple concentration of zinc, would assist in determining whether observed values for zinc content at any particular growth stage represent "sub-optimal" concentrations.

Heavy applications of superphosphate have been observed to induce or to intensify symptoms of zinc deficiency in citrus (West 1938), flax (Millikan 1946, 1947a; Cass Smith & Harvey 1948), oats (Riceman 1945), and subterranean clover (Powrie & Riceman, unpublished data), but no attempt has been made to determine the mechanism by which this is brought about. It may be significant that all these species are rather susceptible to zinc deficiency (Forster & Hore 1939; Millikan 1942; Adam & Piper 1944; Riceman 1945, 1948a; Trumble & Ferres 1946), and that lucerne, which is remarkably resistant to this deficiciency (Riceman 1945, 1948a; Anderson 1946b; Trumble & Ferres 1946), flourishes where dressings of superphosphate as high as 8 cwt. per acre are applied without any zinc supplement (Riceman 1948a; Riceman & Powrie, unpublished data). At the other end of the scale, certain weeds, notably *Fumaria officinalis*, will tolerate a concentration of zinc that is too high for flax (Millikan 1947b).

It is fortunate that zinc deficiency in susceptible crops and pasture species can be prevented by relatively light dressings of zinc sulphate. Quantities as low as 5 to 14 lb. per acre are

applied to cereals and pastures in peat and light soils (Riceman 1945, 1948a, 1950; Anderson 1946b; Dunne, Smith & Cariss 1949; Waite Institute Report 1950), while 15 to 30 lb. is adequate for flax and cereals grown in soils of heavier texture (Millikan 1938, 1941, 1946; Forster & Hore 1939; Adam & Piper 1944; Cass Smith & Harvey 1948). One single application of a dressing as light as these is sufficient to protect the crops and pastures from zinc deficiency for many years. In this regard it is interesting to find that the quantity of zinc added inadvertantly to these soils may amount to the equivalent of ¼ to ½ lb. of zinc sulphate for every 1 cwt. of superphosphate that is applied (Walkley 1940; Oertel and Stace 1947; Dunne & Throssell 1948). This is sufficient to replace most, if not all, of the zinc removed by a high yielding wheat crop (Walkley 1940). Such small quantities of zinc may be of no consequence in the initial prevention of zinc deficiency in crops and pastures in zinc-deficient soil (Walkley loc. cit.; Powrie & Riceman, unpublished data), but their regular addition as an impurity in superphosphate probably delays the need for further deliberate applications of zinc.

Molybdenum

It is not long since molybdenum was first discovered to be a limiting factor in the growth of legumes in certain acid soils in South Australia (Anderson 1942). The discovery stimulated a search for the existence of a similar condition elsewhere. There are reports now of molybdenum deficiency in pasture legumes, chiefly subterranean clover and lucerne, in several other States, and further occurrences have been observed in South Australia (Fricke 1943, 1944, 1945a, 1945b; Stephens & Oertel 1943; Shaw, Barrie & Kipps 1944; Teakle 1944; Trumble 1945; Trumble & Ferres 1946; Anderson 1946a, 1948; Anderson & Spencer 1949; Northcote & Tucker 1948). In Tasmania, a disease in oats known as "Blue Chaff" has been controlled by applications of molybdenum (Fricke 1947). Reference will be made later to the occurrence of molybdenum deficiency which is thought to be associated with manganese toxicity.

New Zealand work provided the clue to the cause of "Whiptail" disease in cauliflowers, and dressings of molybdenum are now commonly used in vegetable-growing areas in Australia to control not only "Whiptail" (Waring, Shirlow & Wilson 1947: Wilson & Waring 1948; Waring, Wilson & Shirlow 1948, 1949; Dunne & Jones 1948; Wade 1949a), but diseases in a number of other crops as well (Fricke 1944, 1945a; Wilson 1948, 1949a, 1949b; Anon. 1949a).

The molybdenum deficiency diseases are, with few exceptions, confined to plants growing in soils having an acid reaction. Dressings of lime, wood ash, or other alkaline material are usually effective in alleviating the condition and were commonly

used before it was suspected that molybdenum was involved (Anderson 1942, 1946a; Anderson & Oertel 1946; Stephens & Oertel 1943; Waring, Wilson & Shirlow 1948, 1949). It is now known that the benefit of these dressings can be attributed to their influence on molybdenum availability (Oertel, Prescott & Stephens 1946).

Effective control of the deficiency is obtained by direct applications of molybdenum to the soil. The quantities applied are extremely small. No more than 1 to 2 oz. of molybdenum trioxide per acre are required to give complete control of the deficiency in subterranean clover (Anderson 1946a, 1948). Rather heavier dressings, mostly in the form of ammonium molybdate or sodium molybdate, are applied to vegetable crops (Waring, Shirlow & Wilson 1947; Waring, Wilson & Shirlow 1948, 1949).

A spectrochemical survey of phosphate rocks of different origin, and of superphosphate made from them, has revealed differences in the amount of molybdenum present (Oertel & Stace 1947). No molybdenum was detected in rock from Nauru and Ocean Island, where Australia's supplies are normally procured, but rock from Egypt, Algeria and Florida contained traces of molybdenum amounting to several parts per million. The superior results that are occasionally obtained in molybdenum-deficient areas with some superphosphates may be due to this impurity (Trumble & Ferres 1946; Millikan 1948-1949), since it is known that deliberate applications of as little as 1/16 oz. of molybdenum trioxide per acre to deficient soil can exert a beneficial effect on the growth of subterranean clover (Anderson 1946a).

The restricted growth of subterranean clover plants in molybdenum-deficient soils is due to nitrogen deficiency in the host-plant, brought about by a breakdown in the process of symbiotic nitrogen fixation (Anderson 1946a, 1948; Anderson & Thomas 1946; Anderson & Oertel 1946; Anderson & Spencer 1949). The host-plants are not directly affected by the molybdenum deficiency. They respond vigorously to dressings of nitrogen fertilizer where no molybdenum is added. Grasses behave similarly.

Subterranean clover grown in the affected soils may not derive full benefit from applications of molybdenum unless the plants are adequately manured with phosphate (Anderson 1946a). In this the host-plant is concerned directly (Anderson & Thomas 1946; Anderson & Oertel 1946). A parallel case has been discovered where sulphur deficiency inhibits a molybdenum response by subterranean clover. The nitrogen metabolism of the host-plant, in this case, is limited directly through lack of sulphur, while symbiotic nitrogen fixation is limited through lack of molybdenum (Anderson & Spencer 1949).

The concentration of molybdenum in healthy plants of lucerne and subterranean clover is found to be extremely low; it seems that a concentration of not more than 1 part of molybdenum per 10 million of dry weight of leaf and stem is adequate

for normal metabolism of the host-plant (Teakle 1944; Anderson & Oertel 1946; Oertel, Prescott and Stephens 1946). In these species, and in several other legumes that have been examined, more molybdenum is found in the roots than in the tops, and much more is found in the nodules than in the tissues of the root itself (Jensen and Betty 1943).

In crops that are affected directly by molybdenum deficiency, such as vegetable crops, nitrogen metabolism is upset and this leads to an accumulation of nitrate in the tissues and to the development of pronounced lesions on the leaves (Piper 1940a; Fricke 1947; Wilson & Waring 1948).

In some soils, molybdenum deficiency is associated with manganese toxicity. This has been observed in subterranean clover (Anderson 1948), in beans (Wilson 1949a), and in flax (Millikan 1948-1949). Addition of molybdenum appears to alleviate the condition by producing some measure of tolerance to the high concentrations of manganese. This is supported by laboratory investigations, which have demonstrated an effect of molybdenum in reducing the symptoms of toxicity induced in flax by high concentrations of manganese and several other heavy metals (Millikan 1947c, 1948, 1949).

FUTURE TREND

From this review it will be evident that research into the trace element deficiencies in Australia has been directed very largely to the solution of the immediate problems of prevention or control. Rapid progress has been made during the past decade, but further advances are becoming ever more dependent upon an extension of basic knowledge. For this it is no longer sufficient for us to depend upon our colleagues overseas, and so in Australia now the emphasis in research is shifting from the practical to the fundamental aspect of nutrition, and the species under observation are the ones most commonly employed in our own deficient terrain.

Such a change in the direction in which research progresses is naturally a slow one, but in the future we may hope to see advances that will enable us to comprehend more clearly the true significance of our experimental findings.

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THE SIGNIFICANCE OF TRACE ELEMENTS IN RELATION TO HEALTH OF RUMINANTS IN GREAT BRITAIN[1]

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The purpose of the present paper is to provide a brief review of the significance of the so-called "trace elements" or "minor elements" in relation to disorders of ruminants as they occur in Great Britain, in comparison with occurrence of similar disorders in other parts of the world.

Pigs and poultry are omitted from consideration, partly because of differences in requirements of animal species, partly because so much of the food in their mixed rations is imported and not characteristic of any one farm, and partly because of the occurrence of minor elements in the mineral mixtures normally fed to them to ensure adequate intake of major elements. At any rate, they do not seem to present the definite regional problems characteristic of ruminants restricted to pasture and supplementary foods grown on single farms or definite geographical areas.

As well known to all agricultural chemists and physiologists, the number of minor elements found in plant and animal tissues is very large, and traces of almost any element present in soils can appear in a plant simply because they are brought into solution by the action of its roots and can not be entirely rejected. Some of these are inert, like nickel, which is always present in soil grown vegetation but without which the plant grows equally well in water cultures from which the element is carefully excluded, and upon which no known physiological process of the consuming animal is known to depend. Others, such as boron, are essential for plant health and hence find their way into animal tissues where, however, they are not known to serve any useful purpose. A third group, exemplified by selenium, serve no useful purpose either in plants or animals but can be tolerated by certain species of plants in such large quantities that they cause "selenosis" (the old "alkali disease" of South Dakota) in animals consuming them.

The "trace elements" only become economically important if they happen to be essential micro-nutrients, the absence of which causes "deficiency disease," or if they occur in soils in excessive amounts injurious to plants or animals, or if they appear as the result of contamination by industrial processes.

It is proposed to limit consideration to manganese, iodine,

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cobalt and copper, as examples of essential micro-nutrients, molybdenum as example of a minor element important in Great Britain when present in pastures in injurious amounts, and fluorine as example of a minor element which has come into prominence in recent years through industrial contamination of pastures grazed by ruminants.

Manganese

This element is mentioned only because of prevalent misconceptions concerning its importance. Although it is an essential micro-nutrient in animal life and, on the basis of experimental work on rats it is believed to affect growth rate, skeletal metabolism, ovulation and development of the foetus, when the adequate traces are not available, it is usually present in sufficient amounts in the vegetative parts of plants to cover the requirements of grass-eating animals. This is true even when soil conditions are such as to lead to definite symptoms of manganese deficiency in susceptible plants, and it is not uncommon to see signs of manganese deficiency in oats, wheat and peas grown on cultivated soil, when adjoining similar soil under grass is carrying perfectly healthy cows showing none of the signs of manganese deficiency which would be expected from the known effects of experimentally induced deficiency in small laboratory animals.

Some years ago the view was put forward by Hignett (1941) in Britain that a form of delayed ovulation in the larger farm animals, when the female comes into heat and accepts the male before descent of the ovum, could be attributed to manganese deficiency of pasture occasioned by excessive liming of the soil. Subsequent investigation, however, involving attempts to control the temporary infertility by manganese therapy, has not substantiated the view and it has been abandoned by Hignett himself.

The converse case of possibly injurious effects of high manganese in pastures can also be dismissed as highly improbable. An earlier suggestion (Blackmore et al. 1937) that high manganese was conducive to hypomagnesaemic tetany failed to find corroboration in experimental observations of Allcroft (1937), and has not stood the test of time.

Iodine

It is hardly necessary to mention that iodine is required for the formation of thyroxine, the hormone of the thyroid gland, and that goitre is the common sign of dietary deficiency. Daily animal requirements are small, however, and traces of the order 0.05 mg.-0.10 mg. per 100 lb. body-weight are sufficient. Nevertheless, acute iodine deficiency occurs in farm stock in many parts of the world, manifested as congenital thyroid hyperplasia in piglings, calves and lambs, and less commonly as goitre in adult

cattle, sheep, goats and pigs. It should be emphasized, however, that direct iodine deficiency in the food is not the only cause of thyroid hyperplasia, and that any factor which reduces absorption of iodine, or increases the utilization of thyroid hormone, may increase normal demand, and that substances may be present in plants which interfere with the proper metabolism of the thyroid gland itself.

In Great Britain typical iodine deficiency in farm stock is very rare, but has been recorded in both lambs and calves, notably by Jamieson *et al.* (1945 and 1947) and associated with characteristically low iodine content of the thyroid gland.

The type of "conditioned iodine deficiency" brought about by some "goitrogenic factor" in the food is also recognized, and an extreme case of naturally occurring congenital thyroid hyperplasia in lambs, resulting from excessive feeding of kale to pregnant ewes, may be cited (Shand & Allcroft 1950). The outbreak occurred in the spring of 1949 in a flock of 500 Oxford cross-bred ewes in Nottinghamshire, many of which delivered still-born lambs or lambs which died a few minutes after birth, showing notable thyroid hyperplasia. Associated with this was the fact that the kale crop had been exceptionally good and provided the major ration during the gestation period. This suggested the "goitrogenic factor" known to be present in cabbage and it was decided to attempt to reproduce the condition experimentally the following year. The main flock fed under ordinary farm management on roots, grass and hay, was limited to a small amount of kale and, to protect the farmer in case genuine iodine deficiency was involved, was hand-dosed at fortnightly intervals with potassium iodide. Two groups of 50 each, however, were isolated for experimental purposes, one fed on the same ration as the main flock but without the supplementary iodine and the other fed exclusively on kale from tupping time until lambing. The kale supply, and practical difficulty of isolating a third group, prevented inclusion of a trial with "kale only plus iodine" but the limited results dramatically established kale as the causal factor. The lot fed roots, hay, and limited kale, lambed normally with an average of three lambs for every two ewes. The lot fed exclusively on kale averaged less than one surviving lamb for every two ewes. Some of the ewes aborted and of the lambs which were born alive a large proportion died within a few hours with enlarged thyroid glands, the largest of which weighed 270 grams. Iodine determinations on blood of the ewes at intervals during gestation showed no difference in total iodine and protein-bound iodine, as between those fed exclusively on kale and those fed on limited kale, although the ewes of the main flock receiving iodine showed, as would be expected, much higher values. Iodine values on all the enlarged thyroid glands of the lambs in the kale group were low although not all as low as was expected. The experiment is being repeated for 1950-1951, including an iodine supplement to a

kale fed group, but provisionally it is anticipated that iodine may not act prophylactically. The clinical condition in the lambs did not suggest low iodine goitre as known in iodine deficient areas, but rather suggested an anti-thyroxin factor interfering with the metabolism of the gland in spite of adequate iodine intake. Even those lambs with only moderate thyroid hyperplasia, and which could have been expected to survive, died on the day of birth, often within a few minutes of delivery. Few of the ewes themselves showed any obvious abnormality—thyroid enlargement in this case was not palpable except in one or two instances.

COBALT

There is no need to recapitulate the classical work on cobalt deficiency in Australia and New Zealand, where occurrence was on the grand scale in some areas until the etiology of various obscure conditions was cleared up by the work of Underwood and Filmer (1935) and of Marston and Lines (1935).

In Great Britain "enzootic marasmus" of cattle does not appear to have been specifically recorded except on the Isle of Tiree in the Hebrides, but subdued cobalt deficiency doubtless exists in cattle in areas where "pine" of lambs is well established. In Scotland, "pining" or "vinquish" in lambs has been known as a debilitating disease from time immemorial, was attributed to iron deficiency in the late twenties, and definitely shown to be due to lack of cobalt in 1938 (Corner and Smith, 1938) when Australian work became well known. Since that date the most valuable work in Scotland has been done by collaboration between the Macauley Institute for Soil Research in Aberdeen and the Moredun Institute of the Animal Diseases Research Association at Edinburgh. A map of the affected areas was given by Stewart, Mitchell and Stewart (1946) and further investigation is rapidly adding to its scope and accuracy. Large tracts of land north of Inverness are affected, and specific districts in the Solway area and Roxburghshire in the south have been defined. In England the areas most definitely affected are the granite and sandstone soils of Devon and Cornwall investigated by Patterson (1946).

Other areas of Great Britain are also affected to a lesser extent and forms of subdued cobalt deficiency have been reported from the Northern Counties in England, from the Fens of Norfolk, and hill lands of Wales, but no systematic mapping has yet been undertaken and the true position is uncertain. It has been suspected but not yet investigated in Ireland, on soil formation similar to those of affected areas in England and Scotland.

In general the course of investigation has followed the lines of Australasian work very closely and the method of dealing with the problem is much the same. Where pastures are under proper management fertilization of the soil with the requisite small quantities of a cobalt salt is the simplest procedure. The

Scottish workers favour an application of 2 lb. per acre of cobalt sulphate once in a rotational course of four years, as compared with the annual application of 5 oz. per acre favoured in New Zealand. Where the value of the land does not repay systematic pasture management as with much of the rough hill grazing in various parts of affected country, reliance is placed on suitable mineral mixtures offered *ad libitum* or on oral dosing as often as the shepherd can manage it.

The safe lower limit for cobalt in pastures in Britain is taken as about 0.08 p.p.m. on the dry matter and it is considered highly unlikely that healthy lambs can be reared on pastures containing less than 0.05 p.p.m. It will be noted that these figures are very similar to those derived from Australia and New Zealand.

Since it is often difficult to secure pasture samples free from a degree of soil contamination which may invalidate analytical results, the Macaulay Institute in Aberdeen prefers soil analyses for survey purposes. Figures for total soil cobalt have little significance but the moiety extractable with 2.5 per cent acetic acid is regarded as a fairly reliable index. The range 0.25-0.30 p.p.m. for acetic-soluble soil cobalt is treated as critical.

The function of cobalt in the animal economy is still obscure, but the fact that naturally occurring cobalt deficiency diseases are confined to ruminants, and are unknown in non-ruminants, at once suggests a functional relationship. That the rumen is specifically involved was indicated by an observation of Marston in Australia about 1940 (not published until later), to the effect that cobalt administered by mouth to cobalt deficient sheep was vastly more effective than cobalt administered intravenously. The reason for this behaviour has been under investigation at the Rowett Institute in Aberdeen, the most recent observations being those of Phillipson and Mitchell (1950). These workers maintained lambs in a cobalt deficient state on a ration of cobalt low hay, flaked maize and maize gluten meal supplemented with cod-liver oil and bone flour, and found that 0.1 mg. Co per day was sufficient to allow normal increase in weight, but that the same daily dose by intravenous injection had no effect, although it led to liver storage of the element. Using various fistulae cobalt was introduced separately into the rumen, abomasum, and duodenum. Good responses were obtained, rather variable in the case of duodenal introduction, but the rumen liquor of all the treated animals contained more cobalt than that of the controls, indicating a backward leak vitiating deductions. They concluded that their observations support the suggestion of Marston and Lee (1949) but do not exclude the possibility that free cobalt is necessary in the abomasum itself.

Molybdenum

British pastures may be regarded as containing a common normal of about 1 p.p.m.-3 p.p.m. Mo expressed on the dry mat-

ter, and this level is regarded as beneficial. Normal traces are certainly important for fixation of atmospheric nitrogen by free-living *Azotobacter* in soils and the nodule bacteria of legumes, and Mulder (1948) has assigned a specific function to molybdenum in the nitrogen metabolism of the plant. The lower limits of molybdenum in British pastures have been little investigated, and it is not known whether traces of this element are essential to animals or not, but it is quite certain that it can be taken up from some soils in such excessive amounts that it becomes harmful to grazing ruminants.

The clearest cases of "molybdenosis" occur on the so-called "teart" soils, derived from the molybdeniferous lower lias geological formation in Somerset. Although the association of "teart" pastures with a "scouring disease" of ruminants had been recognized for centuries it was not until about 10 years ago that the explanation was found by workers at Jealott's Hill (Ferguson, Lewis and Watson 1943) and prophylactic measures devised. The disorder mainly affects cows in milk and young stock. Sheep are less affected and horses not at all. Diarrhoea may commence even within 24 hours of putting cattle on to affected pastures in Spring, and the dung soon becomes watery, evil-smelling, and yellow-green in colour. The animals become filthy, develop staring discoloured coats (not true "depigmentation" of hair fibres) and lose condition rapidly, eventually suffering permanent injury or death. The rapidity with which recovery ensues on transfer to non-teart pastures is very characteristic.

The area concerned in central Somerset comprises about 20,000 acres and smaller areas are found in North Somerset, Gloucester and Warwick. So far as is known the problem is negligible in other areas of Britain. The pastures of non-teart areas in the same county are usually below 3-5 p.p.m. Mo (D.M. basis), and rarely exceed 5-7 p.p.m., although occasional values as high as 9-11 p.p.m., and rarer values as high as 20 p.p.m. appear in various parts of Britain. But in the Somerset "teart pastures" figures up to 100 p.p.m. are encountered and figures well above 20 p.p.m. are common. The severity of scouring is directly related to the water-soluble molybdenum in the grass, which is highest during the active phase of growth and lowest in old grass. Diarrhoea, therefore, usually commences in May and ends in October.

The disease is a straightforward "molybdenosis" and can be produced in a few days in stalled animals by dosing with sodium molybdate, on a ration not itself conducive to constipation, or by putting cattle on any growing pasture dressed with molybdate in amount sufficient to bring the molybdenum content up to "teart" levels. The mechanism of the scouring effect is not yet understood but it concerns only the alimentary tract, and the diarrhoea can be controlled by the therapeutic use of copper sulphate, a procedure well known in veterinary practice for most

forms of scouring, even those of bacterial origin. A daily dose of 1 gm. for young stock and 2 gm. for cows, administered most conveniently as ½ lb or 1 lb of "anti-teart cake" (copperised dairy cubes) is sufficient to enable the grass to be used right throughout the season. This has little or no effect on the absorption of molybdenum and levels of this element in the blood and urine of the cattle remain high without apparent adverse effect. In "teart" areas the severity of the disease can also be mitigated by cultural procedures or the land used for controlled purposes other than grazing. Legumes absorb more molybdenum from the soil than grasses. Little absorption occurs on acid soils, but on alkaline or neutral soils uptake by plants is rapid. Animals in very good condition on supplementary feeding for milk production seem less prone to scouring at grass than animals limited entirely to high molybdenum pastures.

At first this English "teart" area seemed to represent a geological curiosity, but a few years later Britton and Goss (1946) reported a disease in California resembling "teart" and have since (personal communication) found pasture levels of molybdenum even higher than those in Somerset.

Of interest also is a case of "industrial molybdenosis" now under investigation near Glossop in England. The factory concerned produces various alloys, mainly special steels, and uses large amounts of molybdenum. Some of this escapes with the chimney effluents and contaminates pastures in the direction of the prevailing wind. Scouring of grazing dairy cows ensues and typical "teart" appears.

Fluorine compounds are also emitted and the clinical picture is one of molybdenosis, hypocupraemia, and mild fluorosis.

Copper

Although evidence of copper deficiency in live-stock seems to have been first supplied from Florida in 1931 and Holland in 1933, the most valuable work over the ensuing years has come from Australia. It was not until 1938 that copper was definitely associated with disease in sheep in Britain and not until 1946 that hypocupraemic disorders of cattle came under observation.

Several complex clinical conditions associated with low copper status are now recognized in England, Scotland, Wales, and Ireland, nearly all on pastures normal in copper content. The very low pasture copper levels recorded in some parts of the world, 3 p.p.m. or less, have not yet been observed in Britain and it is believed that "straight copper deficiency" in ruminants does not occur; that recognized disorders associated with hypocupraemia and low liver copper are all "conditioned"; and that there may be a variety of conditioning factors different in character.

Sheep

The disease 'neonatal ataxia of lambs' has a wide geographi-

cal distribution throughout England, Wales and Scotland, but has not so far been reported from Ireland although the occurrence there of hypocupraemic disorders in cattle (Senior 1950) would suggest that this disorder of sheep also occurs in some areas. It has been known for many years in Britain under a variety of names, such as "swayback," "swingback," and "warfa," and has been shown to be pathologically similar to "enzootic ataxia" of lambs in Australia as described by Bennetts and his colleagues (Bennetts and Chapman, 1937; Bennetts and Beck, 1942), and to "renguerra" in Peru described by Gaiger (1917).

Although the disease has a wide distribution throughout Britain, the incidence varies from year to year on the same farms and in the same districts, but there are some areas, notably parts of Derbyshire, where it occurs year after year, the only variation being the percentage of lambs affected each year. Before prophylactic measures were taken the mortality in severely affected areas varied annually from 5 to 50 per cent of the lambs born. Ewes of any age or breed may give birth to ataxic lambs, and ewes which produce affected lambs one year, may produce normal lambs the next, but in our experience occurrence of the disease is broadly related to length of sojourn on 'affected' farms. Observations made in Derbyshire over a period of six years showed that no ewe which had been on an 'affected' farm for less than $1\frac{1}{2}$ years gave birth to an ataxic lamb.

There appears to be two types of the disease, the common acute form in which the lambs are clinically affected when born, and a 'delayed' type in which clinical signs may develop as late as three months after birth. In both, however, the symptoms are essentially those of a spastic paralysis, particularly of the hind limbs, and vary only in severity. All cases show inco-ordination of movement; severe cases are unable to stand; others may walk with difficulty, sway and tumble. Mild cases show only slight weakness of the hind quarters, particularly when made to move quickly. Severely affected lambs usually die shortly after birth but mild cases often survive, and when bred from later may produce normal lambs. Mothers of affected lambs remain apparently healthy and show no clinical symptoms. No evidence of anaemia associated with low blood status has been observed in Britain, the condition in this respect differing from that in Australia. Innes (1934-35) carried out a detailed pathological study of the disease in England and showed that it is characterized by a diffuse symmetrical demyelination of the cerebrum, varying in extent from small foci in the centrum ovale to gross demyelination of the whole hemispheres with liquefaction and cavitation in extreme cases. Secondary degeneration of the motor tracts in the cord is always present. Fig. 1 gives some idea of the brain lesions. It shows three horizontal sections; the top one is from a normal lamb; the bottom one shows the gross destruction of white matter with extensive cavitation; the middle section shows less severe cavitation.

Figure 1.—The various brain sections give some idea of the lesions produced by "Swayback" of sheep in this important organ. The top one is from a normal lamb; the bottom one shows gross destruction of white matter with extensive cavitation; the middle one shows less severe cavitation.

Evidence at present indicates that demyelination occurs at a relatively late stage of gestation, probably within the last six weeks, i.e. after cerebral myelination has begun. Romanes (1947) has shown that the first myelin appears in the forebrain of the foetus at 96 days.

Since the pioneer work of Bennetts and his colleagues it has been well known that the disease is associated with a low copper status of both ewes and lambs and that it can be prevented by administration of copper to the ewe during late pregnancy. Al-

though not feasible in ordinary farming practice, Weybridge work has shown that a single intravenous injection of 20 mg. Cu as copper sulphate to the mother about six weeks before parturition, will also prevent the disease. Sufficient copper is stored in the liver to tide over the intervening period. Although blood copper values of ewes in areas where the disorder is likely to occur are low, commonly about one-third normal, this is of little value for diagnostic purposes since a ewe with a value only one-tenth normal may still deliver a healthy lamb, and sometimes one twin lamb may show the disease and the other not. All that can be said is that if the blood-copper status of a flock is very low the incidence of 'swayback' in the lamb crop is likely to be high, and that if this low status is elevated by administration of copper the disease will vanish. Our own investigations in Derbyshire showed that 'swayback' could occur if the blood copper of the ewe before lambing fell below 0.06 mg/100 ml., and quite frequently occurred at 0.04 mg./100 ml., but nevertheless occurred in only 14 per cent of those ewes with a blood Cu of less than 0.02 mg./100 ml. This indicates that the copper content of the circulating blood of the ewe is not the sole factor determining the incidence of 'swayback' in the lamb, and that shortage of copper supply to the foetus may not be the sole cause of demyelination during late gestation.

Although 'swayback' of Britain and enzootic ataxia of Australia correspond very closely, there is the important aetiological difference that in Australia the disease occurs on pastures low in copper, below 5 p.p.m. on a dry matter basis and commonly below 3 p.p.m., whereas in Britain it occurs irrespective of copper content and is prevalent in Derbyshire at levels of 7 to 15 p.p.m. or more. In Australia the disease has been attributed to a simple copper deficiency rectifiable by fertilizing the soil with copper salts. In Britain another factor seems to operate, which either depresses the availability of the copper in the plant, or in some way interferes with copper metabolism in the animal itself.

The factor in the pastures which induces the disease in spite of normal or high copper content is unknown, but experimental work carried out at Weybridge about 7 years ago showed that it exists in transportable form. From one farm in Derbyshire showing an average of 15 p.p.m. Cu in the pasture dry matter, 20 ewes, each with low blood copper and each with a past history of bearing 'swayback' lambs, were transferred to Weybridge soon after tupping and there fed in stalls on a ration of oats and straw containing only 5 p.p.m. Cu. The blood copper rose rapidly and all lambs were born normal. In the control group left on the farm, with much higher daily intake of copper, blood values remained low and incidence of 'swayback' was 20 per cent. The following year 20 similar ewes were transferred from the same farm along with farm hay to serve as roughage in the Weybridge ration. This time the blood copper remained low and 4

'swayback' lambs were obtained, an incidence of 20 per cent similar to that amongst the controls on the Derbyshire farm in the same year.

There has been much speculation regarding the nature of the unknown factor. Lead has been suggested but the available evidence is against that view. Many 'swayback' pastures are quite normal in lead content and observations at Weybridge showed that a daily dose of 50 mg. Pb as the acetate to hypocupraemic ewes did not increase the incidence of ataxia in the lambs, nor did a high lead intake produce hypocupraemia in normal sheep even when given in quantities ranging from 100 to 400 mg Pb daily for as long as twelve months.

Dick and Bull (1945) and Cunningham (1946) suggested that a high molybdenum content of the grazing might explain the anomaly of a low copper status in ewes and the occurrence of neonatal ataxia in lambs on pastures which show normal copper content, but our own investigations are not in accord with these views and indicate that molybdenum content of pastures in Britain bears no relationship to incidence of swayback. Herbage samples from farms in Derbyshire where incidence of swayback was high showed normal molybdenum values of 0.6 to 1.8 p.p.m. on dry matter, while on certain farms in the teart area of Somerset swayback is unknown on pastures with molybdenum contents ranging from 15 to 40 p.p.m.

Since the unknown factor need not be inorganic, but might be an organic compound competing for copper in enzyme systems in the same way as 2, 3-dimercaptopropanol (B.A.L.) competes for certain metals when used as a detoxicating agent, large daily intramuscular injections of this compound were given to six normal ewes for periods of four to six weeks before lambing in the hope that it might provide a clue to a type of substance capable of depleting tissue copper. This had no effect on the copper status of the mothers and all lambs were born normal. Concomitant copper balance studies by Burdin (unpublished) at Weybridge, on sheep in metabolism cages, showed that daily injections of B.A.L. did not in fact deplete tissue copper when continued over a period of 4 weeks; blood copper values remained normal and liver tissue showed no diminution in copper content. A slightly increased urinary elimination of copper occurred over the first few days but this was quite transitory and did not affect the monthly balance sheet.

Our present view is that the unknown factor is one affecting the copper storage function of the liver, but that it is not molybdenum.

The "enzootic jaundice" of sheep in some parts of Australia, where an unknown factor seems to operate in the reverse way, causing enormous retention of copper in the liver and symptoms of copper poisoning on pastures quite normal in copper content, has not been observed in Britain. In the observations of Bull (1949) a high normal copper content in plants (15 p.p.m. or

more) associated with a very low molybdenum content (0.1 p.p.m. or less), giving a very high Cu/Mo ratio, favoured the development of an excessively high copper status in sheep. The extraordinarily low pasture molybdenum figures given by Bull, down to 0.03 p.p.m., have not yet been encountered in Britain.

True copper poisoning is, of course, well known in sheep grazing in English orchards sprayed with cupric insecticides, and in this connection it is interesting to note that symptoms do not develop for many weeks and may even appear several weeks after removal from the contaminated vegetation. Apparently the liver becomes packed with copper and break-down of function then occurs quite suddenly.

Apart from "swayback" other clinical manifestations of "copper deficiency," either direct or "conditioned," have not been reported in sheep in Britain, although experiments are now in progress on ewes displaying low copper status in areas in which swayback is not prevalent. It is believed that absence of symptoms in apparently normal hypocupraemic ewes may be deceptive and that in some cases elevation of copper status would be beneficial.

Cattle

It was not until 1946 that the occurrence of hypocupraemic disorders was established (Allcroft 1946 and Allcroft & Parker 1949) in cattle in Great Britain although such disorders had then been known in sheep for eight years.

The two dairy farms on which it was first observed are near the Shropshire-Cheshire border and are situated entirely on flat peat land just below sea-level. The chief clinical features of the disorder were chronic diarrhoea and unthriftiness especially during the grazing season. Because of the almost constant scouring the cows were in poor condition, with rough staring coats, and gave low milk yields, but it was in young stock between weaning and calving that unthriftiness was most marked. These animals were severely stunted, so much so that 2-year old heifers could be mistaken for 8-10 month old calves. These symptoms suggested analogy with "peat scours" of New Zealand described by Cunningham (1944).

Blood samples from both herds showed that copper values were very low, figures of 0.01 to 0.04 mg./100 ml. with a mean of 0.03 mg. 100 ml. being found. The liver copper value of one cow which had been on the farm for 6 years was as low as 5.7 p.p.m. on a dry matter basis, with a corresponding blood copper value of 0.06 mg./100 ml.

Pasture samples taken from fields on both farms at intervals throughout the year gave normal copper values ranging from 8 to 23 p.p.m. on a dry matter basis with a mean of 14 p.p.m. Molybdenum values ranged from 2.3 to 7.4 p.p.m. with a mean of 4.4 p.p.m. Although these are slightly higher than the usual

normal of 0.5 to 2 p.p.m. found in Great Britain they do not approach the "teart" pasture values of 15 to 80 p.p.m. found in Somerset by Ferguson, Lewis and Watson (1943).

Daily administration of 2g. copper sulphate to a group of 8 cows on the larger of the two affected farms resulted in a rapid improvement in clinical condition and milk yield. Blood copper values increased to normal levels of 0.07 to 0.09 mg./100 ml. within two months and were maintained as long as copper therapy was continued. In a similar untreated control group blood-copper levels remained low throughout an experimental period of 18 months, mean monthly values ranging from 0.02 to 0.05 mg./100 ml. Limited haematological studies indicated that there was no anaemia associated with the hypocupraemia. All the calves on this farm showed normal blood copper values for the first 9 months of their lives, probably because they were separated from their mothers and fed indoors on calf meal during this period, but there was a steady decline to average values of 0.04 mg./100 ml. during the next 8 months, associated with grazing for longer periods on the peat pastures.

Transference of two cachectic hypocupraemic 2-year old heifers and a stunted 6 month old calf still with normal blood copper from the experimental farm in Shropshire to normal pasture at the Weybridge laboratory resulted in a marked improvement in clinical condition but not in increased blood-copper values. With the heifers, low values persisted for 15 months; with the calf there was an unexpected decrease to less than one-third normal. Change from grazing to winter feeding in stalls resulted in a rapid increase in blood copper in all three animals. Explanation of the anomalous behaviour of these animals is not apparent yet, although it may be related to the original disturbance of liver functions, but the influence of indoor and outdoor conditions is under specific investigation.

Since these initial observations on "conditioned" copper deficiency in dairy cows in Shropshire, "hypocupraemic" disorders of cattle have been observed in various parts of the country and their incidence and distribution are at present under investigation. Because of the possible economic importance of a subnormal copper status a blood survey of selected herds throughout England, Wales and Scotland is being carried out by the Biochemical Department of the Veterinary Laboratory at Weybridge in collaboration with local Veterinary Investigation Officers, in the hope that hypocupraemia will point the way to closer clinical observations and treatment of subnormal conditions.

During the last 15 months 125 herds in England and Wales have been investigated and of these one third showed hypocupraemia associated with a variety of clinical conditions, many of them readily responsive to copper therapy. The general distribution of observed affected herds is indicated roughly on the provisional map shown in Fig. 2, but it is believed that extension

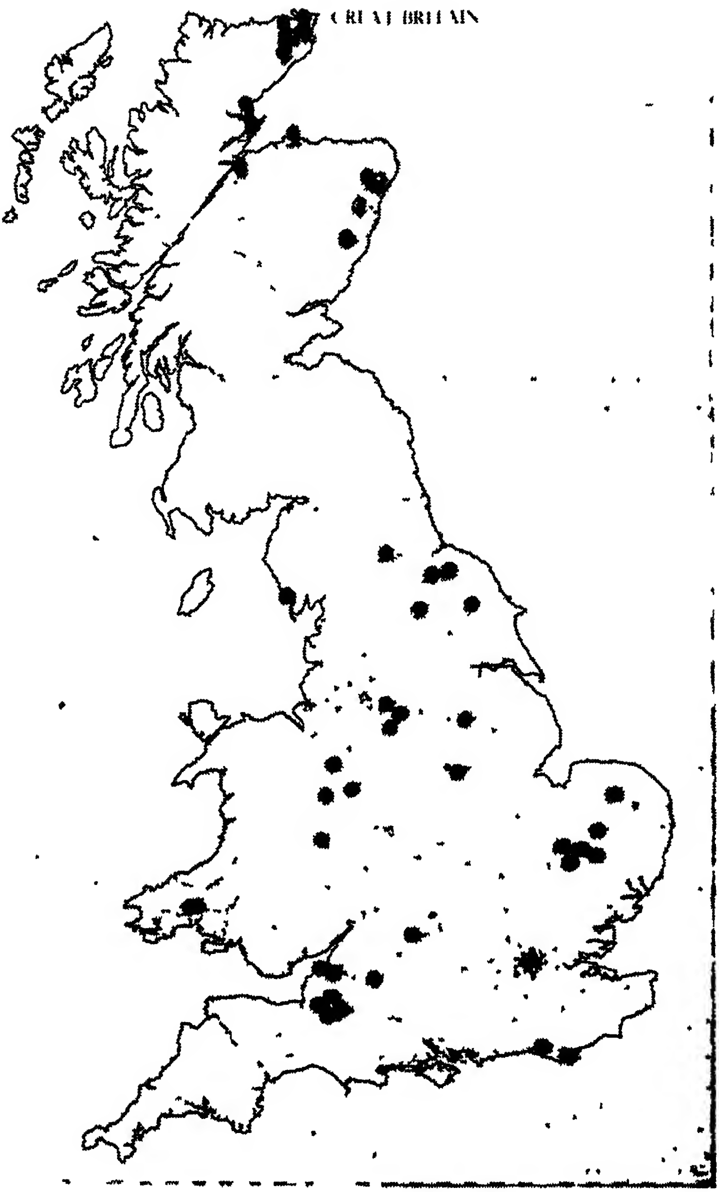

Figure 2.—The black dots on the map of Great Britain indicate areas where hypocupraemic disorders of bovines have been observed during a "blood copper survey" of selected herds during the last 11 months.

of the survey will demonstrate a much more uniform geographical scatter.

Certain areas in Scotland have been subjected to more intensive investigation and in the county of Caithness over 200 farms have been surveyed because of the occurrence there of a copper deficiency syndrome which so far appears to differ from those observed in other parts of Britain. Of the 200 herds investigated 70 percent were found to be hypocupraemic. In Caithness where cattle are chiefly of the beef breed, it is the calves which are affected much more than the cows. Details of this condition have been described by Jamieson and Allcroft (1950) under the name "Copper Pine." The disorder occurs mainly in cross-bred Aberdeen-Angus and in cross-bred Highland calves. In this country cattle are housed in the winter, calves are born during April and May and are then pastured with their mothers until the calves are sold in autumn at about 6 months old.

The first symptoms usually appear about a month after turning out to grass. The calves show a stilted gait, progressive signs of malnutrition follow, and the coat becomes rough, dull and discoloured. In some cases there is a definite change of colour of the black hair around the eyes to grey so that calves have a definite "spectacled" appearance. Diarrhoea is not a constant feature and anaemia is not evident. Unthriftiness becomes more marked as the animals continue on pasture and after about four months the appearance is similar to that shown in Fig. 3. In some seasons the condition develops more rapidly than in others and death may occur at about 4 to 5 months of age. Affected animals which survive and are retained in the herd improve under winter conditions of management, but can be recognized easily the following year by their subnormal development. The typical clinical condition, however, does not recur when they are on pasture during their second year and general appearance improves in later years. The incidence of clinical cases is usually in the region of 25 per cent of the calf population grazing affected areas, but varies on different pastures. In some instances practically all the calves become obviously affected.

Four farms were selected for preliminary experimental observations because of their high incidence of pining in calves. Blood copper values for both cows and calves on all four farms were low, averaging 0.03 mg./100 ml. Pasture samples showed copper figures ranging from 4.8 to 20.8 p.p.m. on a dry matter basis. Apart from the one low figure of 4.8 p.p.m. on a sample of herbage from very rough grazing all the other values fell within the usual normal range of 7 to 24 p.p.m. reported by Eden (1944) for parts of England and Wales. Molybdenum values varied from 1.4 to 19.5 p.p.m. on dry matter on samples from different fields on the four farms. It should be pointed out that the quality of pastures on most farms in Caithness is good,

and that there is no question of the pining condition being associated with insufficient calories and protein.

The effect of copper sulphate therapy was observed in animals on two farms in which the incidence of pining was high. On one a small dose was given once only to two groups of three three-month old calves of cross-bred Aberdeen-Angus breed. One group received the equivalent of 50 mg. copper intravenously, the other of 500 mg. of copper by mouth. A similar group of untreated calves served as controls. On the other farm four calves and their mothers were each given 5 grammes of copper sulphate orally (equivalent to 1,250 mg. of copper) at monthly intervals for three months, while a similar untreated group on the same pasture served as controls.

In both experiments blood samples were taken before treatment and subsequently at monthly intervals. At the end of four months, when the calves were 6 to 7 months old, two untreated control calves and one treated calf from each farm were killed for post-morten examination and estimation of copper in selected tissues.

The results showed that when only one small dose of copper was given, either orally or intravenously, copper figures for blood and tissues were not raised to normal levels, but that clinical symptoms of pine were nevertheless prevented and apparently normal development continued. Fig 4 shows a calf of similar age and breed to that in Fig. 3. Both were kept under identical conditions on the same pasture, the only difference being that the calf in Fig. 4 received 50 mg. copper intravenously when 3 months old. The live weight of this calf was 448 lb. as compared with 336 lb. for the untreated calf shown in Fig. 3. In spite of the prevention of symptoms of pine, all blood copper values throughout the experimental period remained low averaging only 0.03 mg./100 ml. Liver copper was almost as low in the treated calf in Fig. 4 as that in the untreated control calf in Fig. 3, the values being 5.5 and 4.2 p.p.m. on dry matter, respectively. In view of the short period of observation, comments on these findings are reserved until the results of current investigations are available.

Where larger supplements of copper were given orally at monthly intervals, blood copper values in both calves and cows increased throughout the experimental period. Mean values for the calves increased from 0.05 to 0.07 mg. 100 ml and those for the cows from 0.03 to 0.07 mg. 100 ml. Values for untreated controls fell in a similar manner in both groups. The higher copper supplement increased liver copper storage, since a value of 18.9 p.p.m. on a dry matter basis was found in a treated calf, compared with 5.2 p.p.m. in the liver of an untreated control. Even so, a liver value of 18.9 p.p.m. Cu on dry matter is on the low side for a calf of seven to eight months of age. Although the exceedingly small single dose of copper actually prevented pining for the short period concerned, it is probable that doses large enough

Figure 3.—A 6-month old cross-bred Aberdeen-Angus calf showing "copper pine" after grazing on pasture in Carthness for 4 months. Live weight, 336 lbs.

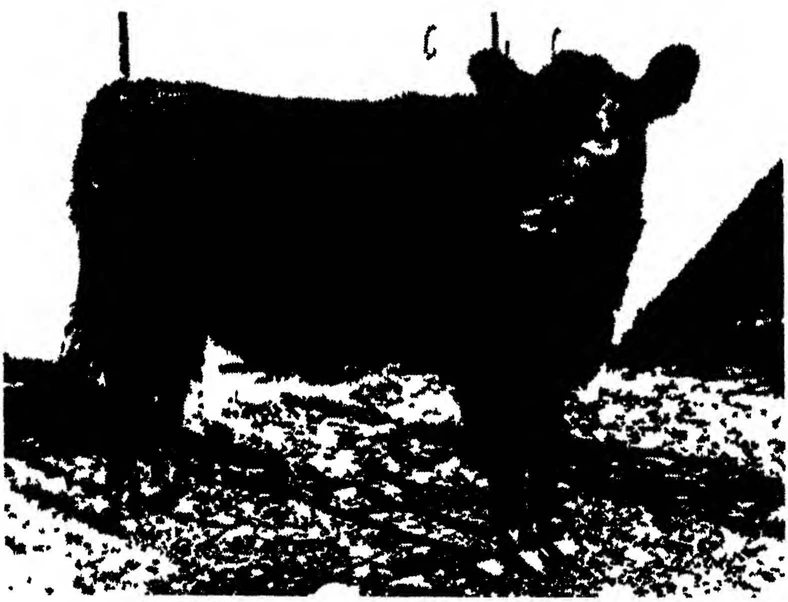

Figure 4.—A calf of the same age and breed as shown in Figure 3 and grazed on the same pasture, but received 50 mg. of copper as copper sulfate intravenously once only at 3 months of age. Live weight, 448 lbs.

to maintain normal values in blood and liver would give better growth and development rates.

It is of interest to note that no anaemia has been observed in this pining condition in calves. Haematological studies made throughout the experimental periods showed that the blood picture was normal in both untreated 'pining' calves and in copper treated healthy calves. In this respect as well as others the condition differs from copper deficiency disorders described by Bennetts *et al* (1941) in Australia, Cunningham (1946) in New Zealand and Davis *et al.* (1946) in Florida.

Repetition of these experimental observations the following year gave similar results. Extended biochemical observations showed that there was no difference in ascorbic acid content of livers and adrenals of 'pining' and copper treated calves nor was there any increase in inorganic P values of the blood as observed by Davis & Hannan (1947). No difference in serum albumin and globulin or total serum proteins was observed but preliminary results of electrophoretic analysis of serum indicate a lower B-globulin content in 'pining' calves.

It has been suggested by analogy that this pining condition in calves in Caithness is due to excess molybdenum in the pastures, and it is true that two fields on one farm where the disease occurs showed the relatively high molybdenum contents of 19 and 16 p.p.m. D.M., but it should be emphasized that calves pined equally quickly and severely on other fields on the same farm where molybdenum values were only 2 to 4 p.p.m., and on adjoining farms where molybdenum values were 1 to 5 p.p.m.

Thus the identical clinical syndrome occurs on pastures of widely different molybdenum contents and it does not seem at this stage that there is sufficient evidence to indicate that molybdenum in these Caithness pastures of normal copper content has anything to do with the low copper status of calves and cows. It is believed that some other "conditioning factor" is involved.

To get more information on optimum dosage levels of copper, and to find the most economical way of supplying adequate amounts of this essential trace element to beef cattle under existing methods of husbandry, various treatments have subsequently been tried on several farms (Jamieson & Allcroft 1950).

On some farms mineralized cubes supplying copper at the rate of 0.3 g. per head per day were fed to cows throughout the gestation period. Observations were made on groups of calves from treated and untreated mothers, and in some groups extra copper was also supplied to the calves.

On other farms no copper supplements were given to the pregnant cows or to the calves but the pastures were top-dressed with copper sulphate during March at the rate of 10 lbs per acre and subsequently grazed by the cows and calves from May until October.

The results of these experiments are not all available yet

but it is evident that pining in calves can be controlled by giving adequate copper supplements to the mothers during the gestation period and by top-dressing the pastures with copper sulphate, although it is doubtful if the latter method would control the disorder unless the pastures were top-dressed anually. Although clinical symptoms of pining were prevented by these two methods of treatment, other results showed that greater gains in weight resulted in calves from treated mothers if extra copper supplements were also given to the calves themselves.

There is still much to be learned about hypocupraemic disorders and methods of treatment and in our present state of limited knowledge caution must be exercised in the interpretation of data.

Copper-Molybdenum Relationships

McCollum *et al* (1939) showed that the hair of rats on an experimental diet deficient in copper becomes depigmented. Since depigmentation of hair had been reported in Holland in cattle suffering from scouring diseases attributed to copper deficiency, and change of coat colour (not true depigmentation) is associated with scouring in the "teart" areas of Somerset, and since both disorders could be prevented and cured by administration of copper sulphate, Russell (1944) suggested that this might be taken as presumptive evidence of copper deficiency in "teart" cattle. She predicated abnormal intake of molybdenum as interfering with the utilization of copper, and reviewed the literature on "teart" in the light of "conditioned copper deficiency." The Australian work of Dick and Bull, (1945) recorded observations indicating that high molybdenum intake in a diet reduced the storage of copper in the livers of cattle and sheep, and brought copper-molybdenum relationships into prominence, and Cunningham in New Zealand (1946) suggested that "peat scours" may be the result of a small excess of molybdenum in the pastures superimposed on a moderate deficiency of copper. Later Cunningham (1949) confirmed the observations of Dick and Bull and showed that a high intake of molybdenum over a prolonged period did reduce liver copper storage; also that it reduced blood copper levels in bovines. This effect of molybdenum on copper storage was confirmed later in the same year by Comar *et al* (1949). Recent results obtained at Weybridge on the effects of prolonged high molybdenum intake on bovines whose copper status was normal before molybdenum administration was commenced, are in line with these observations and reduced liver copper storage has been found but they differ from Cunningham's observations (1949) in that there has been no concomitant decrease in blood copper levels over experimental periods of six to eighteen months. Liver copper values obtained from biopsy samples showed a considerable diminution, while blood copper remained practically constant. It is of interest, however,

that when similar amounts of molybdenum were given to young bovines of initial low copper status brought in from Caithness (liver values 6 to 11 p.p.m.) instead of a reduction there was an increase in liver copper storage associated with an increase in blood copper levels. This latter experiment has been running for only six months and it is too early to say what the final effect will be but these preliminary observations are in line with those obtained at Weybridge in 1948 on sheep of low copper status brought in from Derbyshire. In this experiment six hypocupraemic ewes were transferred from a "swayback" farm to stalls at the laboratory. Two were retained as controls and sodium molybdate administered to four over a period of 15 months in daily doses raised each quarter on the scale 14, 56, 112, 224 mg. Mo. In the later stages blood molybdenum values were running at 100 times normal. Despite this, blood copper levels rose rapidly, from the low average of 0.025 mg./100 ml. to a normal of 0.085 mg. during the first quarter, continued to rise and remained about 0.10 to 0.12 mg./100 ml. in the later stages. This is illustrated in the graph of Fig. 5. At the conclusion of the experiment liver tissue had reached a mean value of 528 p.p.m. on dry matter, as compared with 512 p.p.m. for one of the control sheep and a calculated initial value of about 15 p.p.m. (found in similar sheep on the same "swayback" farm). All six sheep improved in weight on the liberal stall ration, which had an estimated copper content of about 8 p.p.m. on dry matter, and remained in excellent condition throughout with no sign of scouring. In this experiment high intake of molybdenum not only failed to maintain the initial low copper status of the sheep but permitted rise of both blood and liver values to normal levels.

It is difficult at this stage to offer an adequate explanation for the conflicting effect of a high molybdenum intake associated with normal dietary copper, on liver copper storage in animals of initial normal and of initial low copper status but for the moment two factors may be predicated, (a) molybdenum, which may function as a normal regulating factor in liver copper storage and (b) another even more powerful unknown factor which is the operative one in the Derbyshire "swayback" area, where molybdenum content of pastures is normal, and in the Caithness area where "copper pine of calves" is apparently independent of molybdenum intake. In (b) the primary cause of low copper status is not molybdenum and hence mere removal of that cause permits the copper status to return towards normal despite molybdenum subsequently superimposed.

Since no observations on the copper status of animals in the "teart" area of Somerset were reported by Ferguson, Lewis and Watson (1943) a series of investigations was undertaken by the Biochemistry Department at Weybridge in 1947. Blood samples were obtained from cattle which had not had prophylactic copper supplements ("anti-teart" cake) on "teart" farms were generally found to show low blood copper but "hypocupraemic

scours" was also prevalent outside the actual "teart" area, and even within it some farms were found with high pasture molybdenum but with blood copper values above those on adjacent low molybdenum pastures. No clear relationship between blood copper and blood molybdenum could be discerned. Pasture copper on all farms investigated was normal or even high.

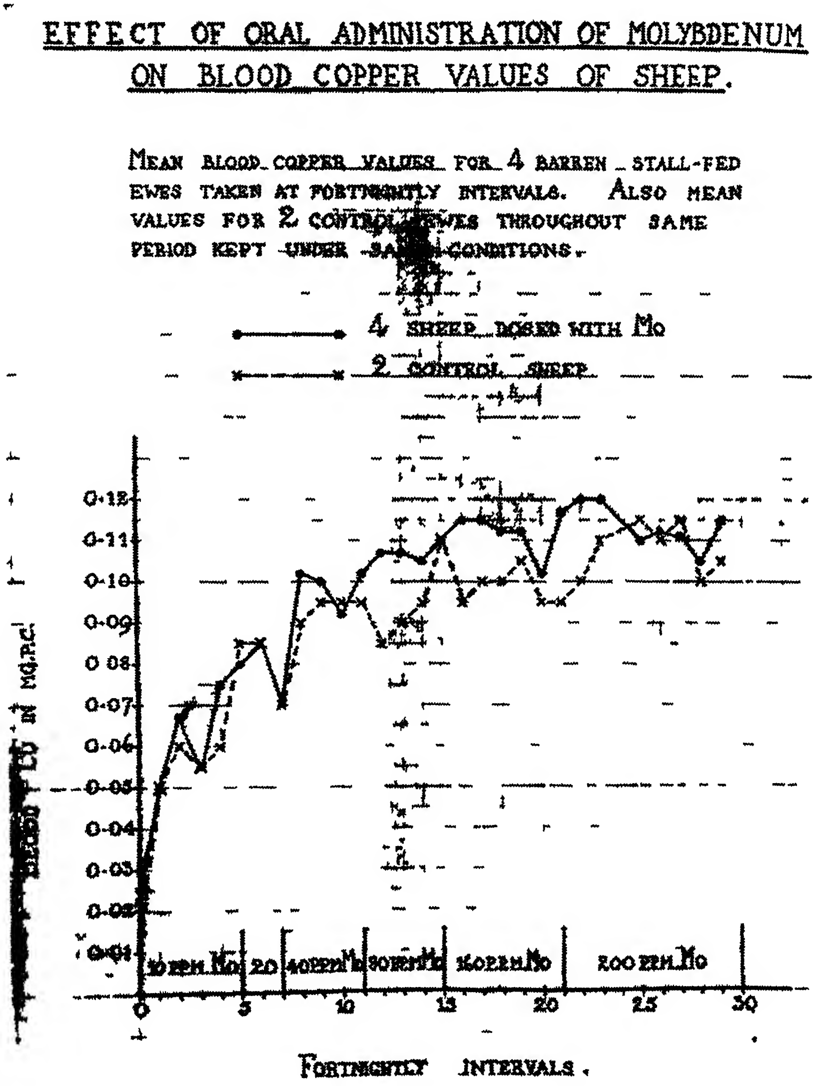

Figure 5—Graph illustrating increase in blood copper levels of hypocupraemic sheep on a high molybdenum intake over a period of 15 months

Six normal heifers sent from Weybridge to a "teart" farm in Somerset, of pasture molybdenum ranging from 16 to 40 p.p.m., commenced scouring in one to two weeks and were left to scour continuously for a further four weeks, during which time no consistent change in blood copper occurred, despite elevation of blood molybdenum. At this point three of them were intravenously injected once only with 300 mg. Cu. as sulphate. Scouring was immediately arrested and did not return for four weeks. In the fourth the scouring was controlled for a similar period by the usual daily oral administration of 2 g. copper sulphate. The remaining two served as controls and continued scouring for six weeks until the pasture became "non-teart" after frosts. Appreciable fall in blood copper ensued in these two, but it is believed that this could have happened with equal probability on a similar Somerset pasture of the non-molybdeniferous type on which "hypocupraemic scours" occurs. Observations on these six heifers has been continued over a further two "teart" seasons (spring and autumn). Scouring in four of them was again controlled by intravenous injection of 300 mg. Cu as sulphate. During the 18 months that these animals have been on the farm four of them have had 300 mg. Cu intravenously on three occasions at approximately 6 monthly intervals. The two controls have been left untreated. There is now a marked difference in the clinical condition between treated and untreated animals. The controls show the usual unthrifty appearance of "teart" animals and their blood copper values have remained between 0.03 and 0.05 mg./100 ml. for about 12 months. Blood copper values of the injected animals averaged 0.075 mg. 100 ml. over the same period and their clinical condition was much better than the two controls although insufficient copper had been given to maintain them in first-class condition.

As for sheep, blood copper levels in a flock of 40 ewes brought in from another area on to the same "teart" farm did not show similar diminution of copper over the same period. Average blood copper figures were still normal at 0.095 mg. 100 ml., after they had been on the farm for three months, although molybdenum values were elevated to 0.082 mg. 100 as compared with a common normal of 0.005 mg. Six months later average copper and molybdenum values were 0.089 and 0.098 mg. 100 ml. respectively and a year later copper figures had not fallen below 0.075 mg./100 ml. in spite of elevated blood molybdenum. Twenty sheep which had been on another farm with pastures of high molybdenum content for three years showed mean blood copper and molybdenum levels of 0.07 and 0.06 mg. 100 ml. respectively. No cases of swayback have been observed on any "teart" farms at all, so far as can be ascertained, and certainly none have occurred during the last three years when farms running sheep have been under our own observation.

The contrast between occurrence of "swayback," with very low blood copper levels, on the Derbyshire pastures of low molyb-

denum content, and the non-occurrence of the disease associated with much higher copper levels on the Somerset pastures of high molybdenum content, is very striking. Obviously the factor inducing low copper status in ewes and demyelination in lambs in Britain is distinct from molybdenum and operates more quickly. High molybdenum *per se* in pastures not only fails to induce "swayback" but fails to induce hypocupraemia in sheep to anything like the extent it does in cattle.

Experiments on stalled cattle at Weybridge in 1948 showed that daily administration of a few grams (2.3 to 6.9) of sodium molybdate produced scouring even on winter rations in 16 to 24 days but some animals were more resistant and did not scour even after six weeks although there was marked loss of condition. Depression of blood copper did not occur and in each of the eight experimental animals there was an increase over this period, from a mean of 0.07 mg./100 ml. to a mean of 0.104 mg./100 ml. despite enormous elevation of blood molybdenum (40 to 200 times). Heifers placed on Weybridge pasture with a copper content of 11 p.p.m. D.M. dressed with molybdate to elevate it to 40 to 60 p.p.m. Mo D.M., scoured severely in five days without significant change of blood copper level but with greatly raised molybdenum level. Injection of 500 mg. Mo as sodium molybdate intravenously on three successive days failed to produce scouring or alteration of blood copper in two cows. No liver biopsy samples were taken during these observations to check its effect on liver copper storage, but recent experiments on three heifers placed on the molybdenised Weybridge pasture indicate that there was an appreciable fall in liver copper values with onset of scouring in 11 days, although there was no fall in blood copper. These preliminary observations require confirmation and, doubtless, some ingenuity in interpretation.

The scouring induced by molybdate administration in stalls or on molybdenised Weybridge pasture could be controlled by oral administration of copper at the usual daily rate, either as the sulphate, carbonate or acetate, but it was observed that single intravenous injections of smaller amounts were more effective. As little as 100 mg. Cu controlled scouring in young animals for several weeks despite continued ingestion of molybdate. This effect of intravenous copper therapy does not support the theory for copper-molybdenum action suggested by McGowan, Brian and Blaschko (1947) without confirmation by experimental work, but is in line with the observations of Davis and Kidder (1949) to the effect that symptoms of molybdenosis are probably not caused simply by uncontrolled bacterial activity in the gastro-intestinal tract.

Nevertheless the "scouring" of "molybdenosis" seems primarily due to disturbance within the alimentary tract, and not to molybdenum circulating in the blood stream. The function of copper, administered *per os* or intravenously, in controlling diarrhoea as such, is under further investigation. Diarrhoea

occasioned by some forms of bacterial infection can be similarly controlled.

FLUORINE

Although fluorine occurs in appreciable quantities in bones and teeth it is not regarded as an essential micro-nutrient and until recently it was considered entirely harmful and only unavoidablely present in animal tissues. Traces are now regarded as useful in protecting against dental caries and, for human beings, water supplies containing up to 0.5 p.p.m. are regarded as beneficial although levels exceeding 2 p.p.m. are definitely harmful. Its significance in animal health only arises when larger amounts are ingested, and this usually occurs by contamination rather than by the presence of abnormally large amounts of fluorine in vegetation, the content of which remains low even when growing on soils very high in the element. The "Oxford Clay" soils containing about 400 p.p.m. of fluorine only show pasture values of 4 to 7 p.p.m.

Spontaneous fluorosis is found in many parts of the world, the most notable diseases being the "darmous" of the rock phosphate areas of Morocco and Tunis and the "gaddur" of the volcanic soils in Iceland. It is the natural water supply which is generally at fault. Darmous is particularly common in sheep, which may die of malnutrition caused by wearing down of the incisors and dystrophy of all the permanent teeth.

The use of ground rock phosphate as mineral supplement for cows has occasioned severe fluorine cachexia accompanied by reduced milk yield, lameness, exostoses on long bones and mandibles, hypoplasia of dental enamel, and other changes. Use as fertilizer is of course quite safe.

The most serious outbreaks of fluorosis in Britain have been of industrial origin, and caused by surface contamination of pastures in the direction of the prevailing winds from large factories emitting fluorine compounds. Since the extent of "industrial fluorosis" in grazing animals is now known to be far greater than formerly believed, it may be of interest to mention a few outbreaks which have been investigated over the last 12 years by the Weybridge laboratory in co-operation with local veterinarians. The data up to the year 1946 have been published by Blakemore, Bosworth and Green (1948) but a brief recapitulation may be presented here.

Shortly before the war serious lameness of dairy cows came under investigation in the vicinity of large brick factories in Bedfordshire, and clinical examination by the local veterinary investigator suggested the fluorosis described in Italy in 1912 in association with a superphosphate factory. This diagnosis was quickly confirmed by pathological and biochemical examination of bones of affected animals. Enormous values for fluorine were found, 1.0 to 2.7 per cent expressed on the "bone ash," as

compared with 0.05 to 0.08 percent for normal cattle in other areas. During life affected animals excreted up to 68 p.p.m. in the urine as compared with less than 5 p.p.m. for normal cattle or less than 10 p.p.m. for cattle several miles away from the nearest factory chimneys. Analysis of samples of urine, as well as of pasture grass and hay, served to construct a map of the affected area. This was found to stretch for about 5 miles along a chain of factories, clinical cases being most severe within a mile of each set of chimneys. Where pasture contamination exceeded 25 p.p.m. on the dry matter severe skeletal changes occurred, provided exposure to risk was long enough. At lower levels of contamination, about 14 p.p.m., milder cases occurred, evidenced by mottling of the teeth.

The origin of the fluorine was found to be the self-burning clay used for brick making, which contained 500 p.p.m. of fluorine and 10 per cent of organic matter. It is the presence of this organic matter which makes the clay so valuable, renders the bricks self-burning, economises in fuel, and improves the texture of the bricks by ensuring even incineration. Each large chimney serves a series of brick chambers at various temperatures, the gases from the hotter chambers serving to dry the wet bricks in the cooler chambers and finally bring them to ignition point, after which they finish at a bright red heat of their own accord. At intermediate temperatures a small amount of oil is formed by destructive distillation and at the highest temperatures silicon flouride is given off. The mixed effluents react in the chimney to form an aqueous oily mist together with gaseous products. Both contain fluorine compounds but only the oily mist particles are heavy enough to be carried down on to the pastures within a mile of the chimneys. These settle on the grass, or are caught by hay, as a dusty oily film, and account for the ingestion of fluorine by the cattle. Hay close to the factories may reach a fluorine level of 100 p.p.m. The contamination is entirely on the surface of the grass. Any fluorine compounds washed into the soil by rain are fixed there in insoluble form and do not enter by the plant roots. Hence the leaves of "root crops" are high in fluorine while the fleshy parts are normal.

Enquiry showed that mild fluorosis must have existed in the area for many years but remained undiagnosed until the expansion of the local brick industry reached a point at which gross contamination of the pasture caused skeletal exostoses and actual lameness in the grazing dairy cows on neighboring farms.

Soon after this, fluorosis in cattle and sheep was investigated in Scotland in connection with the large aluminum factories at Fort William. In this case the origin of the fluorine was the cryolite used as flux in the electrolytic process. Because of the peculiar drift of slow winds in hilly country, contamination of pastures was observed for several miles from the factories, although severity of lesions in animals was not so great as in Bedforshire. The factories are now under reconstruction, with re-

placement of old furnaces by more modern types fitted with "scrubbers" to prevent atmospheric pollution.

About 1945 a third type of industrial fluorosis came under observation in England in the vicinity of open-air calcining of iron-stone.

The local process consists in mixing the damp iron-stone with about 7 per cent of coal, and heaping the mixture into ridges running round the section from which the ore is being lifted. The ridge is then ignited, further layers of coal and ore being added until a height of about 40 feet is reached. The calcining takes about six weeks to complete and the whole discharge of smoke is concentrated at one point in the direction of the prevailing winds for a relatively short time, but during this period contamination of adjoining pasture may be very high and persist indefinitely in harvested hay crops. The exterior of a hay-stack half a mile from a burning ridge showed 490 p.p.m. of fluorine in the exterior layer and 70 p.p.m. at a depth of 2 feet. The object of the calcining is to reduce the weight of the ore and transport costs, and to render it physically suitable for the blast furnaces at smelting centres. The fluorine content of the fresh ore is about 0.12 per cent and of the calcined ore about 0.03 percent, so that three-quarters of the fluorine compounds pass off in the smoke, the particles of which serve as "vehicle" carrying the contamination on to pastures for a distance of about a mile in the direction of the wind.

Yet another outbreak of fluorosis in cattle was encountered in the neighborhood of a colour and enamel factory, and at the present moment several outbreaks are being investigated, both in England and Scotland, in the vicinity of large steel works which use sodium fluoride as flux in the "open hearth" process.

The problem of control of industrial fluorosis can be solved in two ways, one by fitting appliances for trapping the gases and preventing atmospheric pollution; the other by conducting agricultural operations with the known "fluorine hazard" in view e.g. by cultivation of root crops and limiting use of pasturage to short periods of time. Store cattle can usually be fattened on contaminated pasture for a few months but dairy cattle cannot be maintained on affected farms all the year round.

The sequence of events with fresh animals brought on to badly contaminated pasture or hay may be sketched as follows: (1) fluorine is absorbed into the blood stream in amounts depending on the degree of contamination (2) most of this is eliminated in the urine, quickly leading to high "ingestion values," quite commonly 25-70 p.p.m., (3) portion of the circulating fluorine is slowly fixed in the bones, which in the course of six to twelve months may reach values sufficiently high to be reflected as skeletal exostoses and clinical lameness (circa 10,000 p.p.m. on the "bone ash," Fig. 6 shows typical exostoses on the hind limb of a cow), (4) on removal from the source of contamination and feeding on normal rations the urine values rapid-

Figure 6.—Bones of the lower limb of a cow showing extensive exostoses. Fluorine content of the exostoses was 13,000 p.p.m. on the bone ash.

ly fall, but remain considerably above normal (circa 12-15 p.p.m.) for a very long time because of slow removal of stored fluorine from the skeleton in the ordinary course of slow reconstruction of fresh bone; urine values at any given moment are a balance between "current ingestion level" and "skeletal change value"; the urine figures at pasture tend to reflect the current fluorine level of ingested food; a week after transfer to normal rations urine values tend to reflect storage levels and hence the degree of fluorosis, (5) adult animals show no symptoms for many months, and if the contamination is small may not show symptoms for several years, (6) young animals reflect ingestion of small amounts of fluorine by "mottling" of the growing teeth, and degree of contamination of pastures may be such that only young animals reveal it in clinically recognisable forms; the first signs of "clinical fluorosis" should be looked for in the growing teeth of young animals or in slight lameness and cachexia of adult animals.

The easiest method of diagnosis of "incipient fluorosis" is by analysis of the urine of suspected clinical cases, or of apparently healthy grazing animals in suspected districts. Any value below 5 p.p.m. is normal. Any value above 10 p.p.m. in urine is suspicious, and when values exceed 20 p.p.m. a survey of the district for source of industrial contamination is imperative, since legal claims by farmers for compensation may assume serious proportions.

A word of warning should be inserted, however, regarding interpretation of analytical data in relation to legal claims, which are only legitimate in relation to actual economic loss. Urine values reflecting current ingestion may be temporarily high without serious clinical effects. Pasture values are often erratic and short grass behind long grass may be protected. Clinical examination, particularly for dental changes in calves and lameness in cows, is the best guide to severity of fluorosis. It is only when teeth are so badly affected as to interfere with mastication, and skeletal changes so advanced as to cause discomfort, that milk yield is seriously interfered with.

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TRACE MINERALS IN NEW ZEALAND

I. J. CUNNINGHAM"

The agricultural industry of New Zealand has developed chiefly around the production from animals of commodities which can be exported and sold on overseas markets. Such a development has been encouraged by a favourable climate with no great extremes of temperature and with a well distributed rainfall, while a small population and restricted availability of labour have dictated that the highest return must accrue from minimal labour output. The system of farming evolved to meet these circumstances is one in which grazing animals convert permanent pastures, and occasionally other crops, into meat, wool and milk or milk products. The almost entire dependence on pasture for stock food means that each farm is self supporting for its fodder supply, and the high productivity of the land and high carrying capacity has led to the farm unit being relatively small. In consequence New Zealand's stock population can be regarded as made up of many groups of animals, each dependent for its nutrition on food produced within the limits of a small area.

Such conditions offer the maximum opportunity for the development of deficiency disease symptoms in farm animals, should the soils be lacking in any of the essential mineral elements. In certain areas cobalt, copper or iodine has been found deficient to a degree that stock disease results; in some areas there is a dual deficiency of copper and cobalt; and in others there is a copper deficiency accompanied by an excess of molybdenum, which aggravates the deficiency of copper in animals and causes additional disease symptoms. In yet other areas sheep are susceptible to a disease the symptoms of which resemble copper poisoning, though excess copper does not occur in the fodder or soil. A low content of fluorine in New Zealand river waters has been observed and, though no symptoms in animals have been associated with this, the possible significance as a cause of dental caries in humans is under study.

Trace mineral deficiencies different from those known to affect animals have been observed in the plant world. Molybdenum deficiency occurs in cauliflowers and in clovers, and boron deficiency affects both fruit trees and turnips. The possible influence that cultural and fertilizing practice may have in hastening or inducing a trace element deficiency in threshold soils has been noted by the effects and lesions produced in some crop plants. This is referred to in connection with boron deficiency where the heavy use of lime may be a precipitating factor.

Details of the deficiencies mentioned above are discussed below in separate sections.

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COBALT DEFICIENCY.

Cobalt deficiency disease in New Zealand has been known as "bush sickness," "Mairoa dopiness" and "Morton Mains disease," all of which were local names applied to a progressive anaemia and wasting which occurred in cattle and sheep grazed in the deficient area. Bush sickness was first called "bush disease" by Park (1) in 1897 because it was thought that the disease was a legacy from the heavy bush that had covered the land before it was developed into pasture land; the name was changed to "bush sickness' by Reakes in 1912 (2) in an attempt to avoid this misconception since by that time it was realised that the disease could occur on soils which had never carried bush. The term bush sickness is now used as a local popular name for cobalt deficiency disease in cattle and sheep in the Nelson district of the South Island and in the North Island except for the Maiora district. "Maiora dopiness" refers to a similar wasting disease of sheep in the Maiora district of the North Island though in this case as an additional symptom of the disease the bones have been described as light and very fragile (3), (4). "Morton Mains disease" is the local name for a rather less severe deficiency of cobalt which affects chiefly young lambs in parts of the Southland district of the South Island (5).

Investigation into bush sickness in New Zealand commenced about the turn of the present century and attention was fo-

Figure 1.—Cobalt deficient hill land in New Zealand receiving treatment with this element by dusting from the air.

cussed on the most prominent symptom, a progressive anaemia. This suggested to Park in 1898 (6), and to Aston in 1912 (7) that the provision of iron might be beneficial to the stock. Aston developed the iron deficiency hypothesis over a number of years (8), finding less iron in sick pastures than in healthy pastures and eventually effecting cure and prevention of bush sickness by feeding iron compounds, the most successful of which was limonite mined in New Zealand (9). Though there was a large measure of success following the generalized use of limonite there were, nevertheless, some disappointments since not all limonites were equally effective and some proved useless (10). An adequate explanation of the variation in the efficiency of limonites due to variation in their cobalt content was forthcoming after the Australian workers Filmer and Underwood (11) had shown that a cobalt impurity in the limonite was the effective fraction in curing a similar disease named Enzootic Marasmus and affecting cattle and sheep in Western Australia. The application of the results of Australian work to New Zealand showed that the three diseases referred to above all yielded to treatment by cobalt. The development of sensitive chemical methods in New Zealand enabled it to be shown that in cobalt deficiency areas the soil (12), (13), the pasture (14) and the animal (15) all contain less cobalt than similar samples from healthy areas. McNaught (15) has worked out the limits of the contents of cobalt in pastures and in animal livers which are indicative of cobalt

Figure 2.—"Bushsickness" in a young cow induced by cobalt deficiency in the soil and the forage growing on it prior to treatment.

deficiency, and this basis is now regularly employed as a diagnostic procedure for cases of suspected cobalt deficiency. For sheep three months and older, concentrations of below 0.06 parts per million cobalt in the liver indicate deficiency and above 0.1 parts per million, sufficiency; for yearling and mature cattle the level indicating deficiency is 0.05 parts per million and for sufficiency, 0.12 parts per million or higher. Pastures which contain less than 0.07 parts per million cobalt are regarded as deficient.

Affected soils.

The affected soils of the North Island are coarse pumice types derived from the Taupo and Kaharoa ash showers and heavily leached parts of the Mairoa ash shower. This information permits of mapping in broad terms the distribution of possible cobalt deficiency areas in the central part of the North Island, and this system of mapping on soil type agrees well with the occurrence of clinical symptoms in the animal population.

In the South Island and Nelson soils are for the most part of granitic origin and the Morton Mains soils are derived from glacial rock-flour or loess.

The most significant feature of the cobalt deficient soils is their coarse structure and ready leaching character.

Another feature is the capacity of many of the cobalt deficient soils, when suitably fertilized with superphosphate, to grow quantities of pasture of good quality apart from the low content of cobalt. The low cobalt content in soil has no limiting effect on pasture production.

The value to be derived from modern methods of soil classification in the delineation of possible areas of deficiency has been demonstrated by Taylor (16) and Grange and Taylor (17). Taylor's (18) most recent work classifies soils on a genetic basis which shows the inter-relationships of the various soil types. The latter are grouped in suites derived from various parent materials, and within the suite they are arranged in sequence expressing increasing stages of leaching, podzolization, gleying, or other soil process. By a study of the parent material and of its descendents it is possible to determine whether the soil is inherently deficient in any mineral and, if it is not, whether and at what stage of processing a deficiency shows up. An inherited deficiency is found in the intrazonal soil group known as Yellow Brown Pumice Loams where the parent material is a rhyolytic pumice very low in cobalt bearing minerals. In other cases, cobalt deficiency occurs only in the more leached types in certain soil suites, where the loss by leaching is in excess of the replenishment from weathering of soil minerals.

Control.

The control of cobalt deficiency disease in New Zealand has been successfully achieved by the provision of cobalt direct to

the animal and more generally by the practice of topdressing the pasture annually, at a rate of 5 oz. per acre, with cobalt sulphate, usually mixed commercially with superphosphate to form cobaltized superphosphate (19).

Though the modern concept of cobalt action is turning from a direct effect of cobalt to the belief that its effect is indirect and possibly obtained through its action on ruminant microorganisms, it is nevertheless still true that the practical method of controlling cobalt deficiency disease is to provide cobalt to the stock.

This has presented problems to New Zealand farming industry since some of the deficient country is not accessible to farm machinery and some is even too rugged and costs are too high for annual topdressing by hand. Attention has therefore been paid to the length of time over which a single topdressing may remain effective. While 5 oz. cobalt sulphate per acre will keep stock healthy if applied each year it has been found that 20 oz. per acre has maintained pasture levels of cobalt and the health of grazing stock at a normal level for a period of at least 7 years (20). This work was carried out on flat country and now is being repeated on steep country (21) on which the washing action of rain on the cobalt may be different. The results obtained up to the present time show that on very steep and hilly country which was topdressed $2\frac{1}{2}$ years ago with 20 oz. per acre the effect of the single topdressing still persists and the pasture is normal in cobalt content. Obviously the acquisition of further information on this aspect is of the utmost importance for land on which the topdressing costs are high.

Technique of distribution over rough country has also been under examination and it has been shown that the use of aircraft is economic and feasible (22). Spreading cobalt on hill pastures through the faeces of sheep drenched with high levels of cobalt is, however, not practicable, since sheep will not tolerate a sufficiently high dose of cobalt to make this method feasible (23).

A problem of some significance in parts of New Zealand is the effect of a near deficiency or borderline case of cobalt deficiency. Not infrequently the chemical examination of specimens from animals showing some symptoms of unthriftiness gives inconclusive results; the cobalt content is neither low nor normal but is between the two. Further, it is claimed by some farmers on areas on which the classical symptoms of cobalt deficiency do not occur that the provision of cobalt nevertheless results in better growth and higher weaning weights of fat lambs. If cobalt acts, as recent work suggests (24), (25), (26), (27), through growth of ruminant micro-organisms which in turn elaborate a growth factor for the ruminant, then it is not impossible on theoretical grounds that such a borderline deficiency may exist. A partial deficiency of the growth factor would be analagous to subclinical deficiencies of some of the

Figure 3.—Cobalt deficient hill land that has been treated and now carries quite a heavy concentration of stock through the normal grazing season.

growth promoting vitamins. Some work in this connection is at present being carried out.

The diagnosis of cobalt deficiency disease might at first appear simple; it involves the collection of livers or pasture samples, the chemical analysis for cobalt and the interpretation of the results. However, no one of these three operations is without its difficulties. Pasture samples must not be contaminated with soil otherwise results may be misleading; and livers from new born animals, which are more readily available than adult livers, are not reliable as an index of cobalt status. If some other tissue such as blood, which could be obtained readily and without slaughter of the adult animal, could be relied upon for accurate diagnosis, then the problem of collecting suitable samples would be greatly simplified. The examination need not necessarily be for cobalt; it might be for some product of cobalt metabolism. The chemical methods at present in use for cobalt are accurate and a great credit to their authors; the methods are nevertheless complex and time-consuming to the point that a real practical problem is presented in carrying out any work involving large numbers of cobalt analyses. A rapid, simple and accurate chemical method for cobalt determination is urgently needed. Interpretation presents no problem when cobalt contents found for livers or pastures are very low or are normal, and no cases have been experienced in which a low liver cobalt means anything but cobalt deficiency in the diet; the borderline intermediate value which presents the difficult has been mentioned above.

Copper Deficiency.

The existence of a deficiency of copper in New Zealand was first recognized, comparatively recently (28), as one cause of a disease in cattle kept on land reclaimed from peat swamps. It is now known that practically all of the 400,000 acres of peat deposits in New Zealand are copper deficient and that on most of the 250,000 acres of such land developed and used for farming, copper supplements must be supplied to keep stock healthy. The peat soils occur in areas which vary in size from many thousands to a few hundred acres; the larger areas are located in the central part of the North Island and smaller areas at irregular points from the far north of the North Island to the extreme south of the South Island. Most of the deficient peat soils are highly organic, some are mixtures of peat and sand, and others are mixtures of peat and pumice. In some of the peat-pumice mixtures a dual deficiency of copper and cobalt has been found to exist.

Copper deficiency occurs also in leached consolidated coastal sands, on leached sandy soils such as the sandy gum lands, and on other porous soils. The area of copper deficient soils of this nature so far mapped is about half a million acres. The total

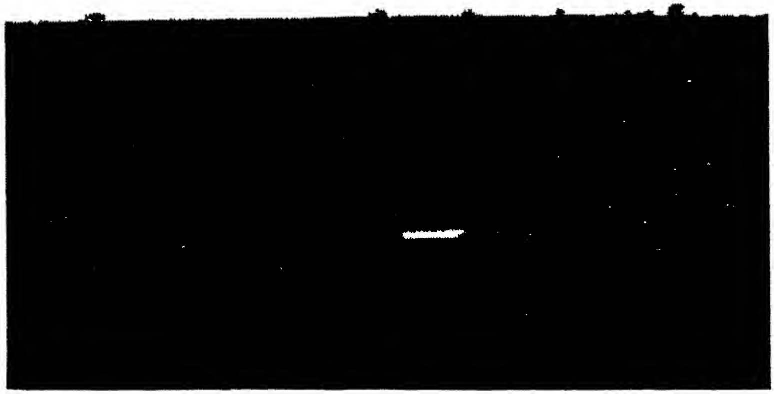

Figure 4.—General view of copper-deficient, peat land in New Zealand.

area affected by copper deficiency in New Zealand therefore approaches three-quarters of a million acres. The degree of deficiency of copper, judged by the copper content of the herbage, is not the same in different areas. Two levels of deficiency have been found; one a moderate deficiency, the other more severe. Most of the peat soils produce moderately deficient pastures which contain about 7 parts per million of copper. On the other hand, small areas of peat and most of the leached soils grow more severely deficient pastures which contain about 3 parts per million copper. These values should be compared with the mean for normal pastures in New Zealand, which is 11 p.p.m. of copper.

Disease in Animals.

In so far as animal disease is concerned, copper deficiency is not the full story. The moderately deficient pastures have, beside their deficiency of copper, a small excess of molybdenum which interferes with the metabolism of copper by grazing animals and aggravates the symptoms of disease in cattle. Such areas are regarded as *Complicated Copper Deficiency Areas.* On present evidence the more severely deficient areas have no such complication and are regarded as *Simple Copper Deficiency Areas.*

Cattle and sheep kept on deficient areas for any considerable length of time become severely depleted in copper and the degree

of depletion is similar despite the different copper intake from pastures of the two types of deficiency.

Two distinguishable diseases of cattle occur, one always on complicated deficiency areas, the other on simple deficiency areas. The symptoms of the *complicated deficiency disease* are poor growth and susceptibility to bone fractures in young animals, and in animals of all ages unthriftiness, anaemia, loss of coat colour and an acute debilitating scouring in the spring season when pastures are lush. Symptoms of the simple deficiency disease are similar except that the characteristic seasonal scouring does not occur. In addition, some young calves develop an ataxia associated with regional demyelination of the nervous system.

There is no differentiation in the reaction of sheep to the two types of copper deficiency. Adult sheep are healthy though depletion of their copper reserves may be very severe. Symptoms of disease first develop only in the very young animals which may be affected by an acute osteoporosis or by a permanent ataxia. Ataxia occurs in lambs of from 3 weeks to 4 months of age whose mothers have been on copper deficient pastures for periods of 2 to 3 years or more; osteoporosis occurs in lambs whose mothers have been exposed to a copper deficiency for shorter periods.

No disease has been observed in horses on copper deficient areas. This may be due, in part, to the use as supplementary fodder of chaff and oats imported from other areas.

Pigs are reported to suffer from unthriftiness and ataxia but no work has been carried out on this species.

Molybdenum and Copper.

So close an association exists between copper and molybdenum in animal metabolism that it is necessary to consider both elements when any disease associated with either one is discussed. Dick and Bull (29) showed that increased molybdenum intake will lower the liver stores of copper in cattle and sheep on a normal diet of copper. This has been confirmed for both species. It has been found also that transmission of copper from the ewe to the foetal lamb is greatly reduced by feeding molybdenum to the ewe. The relative amount of copper and molybdenum in the diet determines the effect of molybdenum. In the sheep, for example, if copper in the diet is relatively high, molybdenum feeding does not retard storage of copper in the liver. Storage of molybdenum in the liver is also influenced by the level of copper in the diet. If sheep or cattle with low copper in the diet are fed molybdenum there is a high storage of molybdenum in the liver, but if the intake of copper is increased much less molybdenum is deposited in that organ. In other words, there is in cattle and sheep a reciprocal antagonism to liver storage between copper and molybdenum.

Concerning the pathological effects of molybdenum on cattle,

Figure 5.—Copper deficiency in New Zealand cattle, above and below, either induced or augmented by an excess of molybdenum in the forage. Ruminents so affected as these can get little good from their feed, of course, while in such a condition of scouring.

copper has an antagonistic effect also. In peat scours, the copper intake is below normal and a relatively small excess of molybdenum induces pathological scouring, which is readily controlled by small supplements of copper enough to bring the supply to normal. In teart (30), a similar scouring disease, dietary copper is normal and a much larger excess of molybdenum induces pathological effects—control also requires higher copper supplies.

To the occurrence of molybdenum and its effect in animal metabolism are referable some of the features of complicated copper deficiency disease in New Zealand. The content of molybdenum in the pastures varies from summer values of 3 to 7 parts per million to 16 p.p.m. in the spring season, whereas in simple deficiency and normal pastures the content varies from 1 to 3 p.p.m. throughout the year. The excess molybdenum accounts for the fact that the liver copper of cattle and sheep on complicated deficiency areas is lower than would be anticipated from the copper content of the pasture. The greater excess in spring accounts also for the seasonal incidence of scouring in Peat Scours. The inhibition of placental transmission of copper in ewes may be concerned with the occurrence of ataxia in lambs on complicated deficiency areas, but our experience indicates that low copper in the new born lamb does not fully explain the development of symptoms of ataxia.

Control of copper deficiency.

On simple or complicated copper deficiency areas control is effectively achieved by supplying copper to the stock.

In the case of sheep New Zealand experience has agreed with that in other countries in showing that ataxia in lambs, once developed, cannot be cured but that prevention can readily be achieved by supplying copper to the mother before parturition. For example a weekly dose of 1.5 g. copper sulphate to the ewe throughout the gestation period is effective; so also is the same treatment administered for the last seven weeks before the lamb is born. A more restricted programme of three doses each of 2.5 g. copper sulphate to the ewe at fortnightly intervals about the middle of the gestation period also prevents all symptoms in the lamb but this method is not suitable for general use as 2.5 g. copper sulphate is near a toxic dose for small ewes. It has been found also that ataxia in susceptible lambs does not develop if they are dosed regularly twice each week from birth onwards with 35 mg. copper sulphate in each dose. For cattle, a treatment that temporarily controls the scouring on "complicated" deficiency land is an oral dose of 3.5 g. copper sulphate and this must be repeated each week to maintain control. Prevention of symptoms in cattle has been achieved by the use of licks containing 2 per cent of copper sulphate, by putting copper sulphate in drinking water or by spraying copper sulphate on

hay, the object of these methods being to supply each cattle beast with about 3.5 g. per week throughout the year.

The most effective, simple and cheap means of controlling the disease in both cattle and sheep is to topdress the pastures with copper sulphate, using 5 pounds on each acre each year in the autumn topdressing (31). The copper sulphate can be employed alone or mixed with lime or any of the usual agricultural fertilizers, the most common form being a commercially produced copperized superphosphate containing 56 pounds bluestone per ton. As a contribution to the problems of distribution of copper sulphate on difficult terrain it has been shown that spreading from aircraft is feasible (32).

With the widespread use of copper as a topdressing on copper deficient land, the problems in stock management have been solved; the diseases caused by copper deficiency have been banished and production has risen to normal.

Indiscriminate use of copper can, however, bring further problems, especially if sheep are exposed to excessive copper intake. This species is much more susceptible to copper poisoning than cattle (33) and in a few instances losses have occurred when the owner supplied too much extra copper where no deficiency existed. Topdressing with small amounts such as 5 pounds copper sulphate per acre, even on land not deficient in copper, does not raise the copper content of the pasture to dangerous levels; the greatest danger is in supplying copper containing licks to sheep.

Copper and Soils.

The total copper content in soil is an imperfect measure of the copper that is available to plants and therefore offers very limited help in applying the results of soil classification to the mapping of areas that may prove deficient for grazing stock. Pasture copper is clearly the most informative measurement when the health of stock is the main consideration but pasture is not always available for all soil types.

Wright and Johnston (34) have initiated work that may prove of considerable value in understanding the influence of parent material and history in the development of a deficiency of copper in various soils. The "available" soil copper is determined by the Aspergillus niger technique of Mulder (35) and a check on the interpretation of this determination is being made by comparing the results so obtained with the copper contents of pastures grown on the same soils.

A number of genetically different soil types (36) have already been examined. Whole suites of soils derived from certain parent materials, such as consolidated dune sands and some claystones, are deficient in available copper, and soils in these suites are regarded as having an INHERITED copper deficiency. For such soils there is commonly a very good correlation between the

"available" soil copper and the copper content of the pasture grown on the soil.

In other soil suites low figures for "available" copper are found as the degree of leaching increases. The weakly leached members of a suite, usually clays or clay loams, give a relatively high figure for "available" copper, whereas the more strongly leached types in the same suite, commonly silt loams or sandy loams, have a much lower "available" copper. This is regarded as an ACQUIRED copper deficiency. In these cases the correlation between "available" soil copper and copper content of pasture is not as close as for inherited deficiency, although the correlation is better for soil types that lie remote from the threshold position.

Examples of results are as follows:

Inherited copper deficiency.

Example. PINAKI SUITE (Intrazonal, strongly weathered yellow brown sands derived from consolidated coastal sands).

	p.p.m. copper "available" in soil.	p.p.m. copper in pasture.
Weakly leached. Whananaki sand (0-4").	1.6	4.1
Moderately leached. Red Hill sand (0.5").	0.8	2.8
Very strongly leached. Te Kopura sand (0-5").	0.3	2.1

Acquired copper deficiency.

Example. MARUA SUITE. (Zonal, strongly weathered yellow brown earths derived from greywacke sandstone).

	p.p.m. copper "available" in soil.	p.p.m. copper in pasture.
Moderately leached. Marua clay loam (0-5").	5.9	6.5
Moderately to strongly leached. Waikare silty clay (0-4").	1.3	
Very strongly leached. Wharekohe heavy silt loam (0-4").	0.6	4.5

Organic soils are regarded as belonging to suites with an inherited copper deficiency as they have a very low total copper content and pastures are low in copper. The aspergillus niger technique invariably gives high figures and the cause of this anomaly is not yet explained.

The classification of soils into inherited and acquired copper deficiency types is important in forecasting the effect that agricultural practice may have on the copper status of the soil and in accurate mapping of present or potential copper deficient areas.

Future Problems.

A problem for the future is the possible further increase in molybdenum content of soil and pasture on complicated copper deficiency areas. Some of the affected peaty soils lie on top of considerable depths of peat, the organic fraction of which can be expected to disappear in the course of time by slow oxidation leaving a new topsoil with higher mineral concentration. The pasture may then take up sufficient molybdenum to produce molybdenosis in grazing stock even when normal amounts of copper are present in the diet, and the difficulties which exist on the teart lands of Somerset (30) may appear here. Further knowledge of copper and molybdenum relations in animal metabolism must be acquired and a study of methods to promote leaching of molybdenum must be made so that feasible control methods can be devised for a farming system that depends almost entirely on pasture as fodder for the cattle.

Another problem concerns the leached sandy soils in which the soil and pasture has been shown to be very low in both copper and molybdenum. The first difficulty might well be the failure of such soils to supply the molybdenum requirements of nitrogen fixing bacteria and therefore the failure to provide an adequate source of nitrogen for grass growth. If molybdenum fertilizers are used complicated copper deficiency might well develop in cattle. Clearly topdressing with copper and molybdenum mixtures is the answer, but data on appropriate levels to use on readily leachable soils has yet to be obtained. There is also need for information on the effect on stock health of grazing on pastures of low copper and low molybdenum content. The results of copper deficiency are known, but the possible effects of low molybdenum in addition have not been investigated. Because of the interrelationships already demonstrated between copper and molybdenum it may not be too much to postulate that some of the biological functions of copper depend upon the participation of molybdenum.

The relation of copper deficiency to fragility of bones in cattle and sheep is another problem which has yet to be examined fully.

Enzootic Icterus.

This disease, known in Australia as chronic copper poisoning (37) and in South Africa as enzootic icterus (38), occurs in some parts of New Zealand. In the central part of the North Island it has been known for some years and most outbreaks occurred on one soil type—Mairoa ash. Recently a series of outbreaks have occurred in the Hawke's Bay district on another soil type—Takapau silt loam.

The disease, which affects only sheep, has associated with it some abnormality of copper metabolism, for one important fea-

ture is that the liver of affected animals contains high levels of copper, and symptoms of the final stages of the disease are in general similar to those of poisoning by repeated doses of copper. There is, however, no more than the usual amount of copper in the soil or in the pasture. Occurrence in New Zealand has been of a somewhat sporadic nature as the disease seldom occurs for more than a few years on any one area. This circumstance has, in fact, imposed a serious limitation to the study of the disease.

In connection with enzootic icterus there is a real need to know more about the copper metabolism of the sheep. This species has a number of unusual features in its copper metabolism: it differs from all other species in having higher amounts of copper in the adult liver than in the lamb liver, which probably means a greater tendency to store copper; it is much more susceptible than the bovine to chronic or acute copper poisoning; and sheep grazing on pasture display a considerable seasonal variation in copper content of the liver. These features all indicate some difficulty in handling dietary copper and thus may have some bearing on the end result in enzootic icterus.

Dietary molybdenum has the same effect on sheep as on bovines in reducing copper levels in the liver but the significance of this in relation to enzootic icterus is not by any means clear. Other related elements like tungsten and rhenium do not show the same effect.

Iodine Deficiency.

In parts of New Zealand both humans and domestic stock are subject to simple goitre. This is rather unaccountable since the disease is at present regarded as due at least in part to lack of iodine in the diet and since New Zealand is a long narrow country regularly subjected to the influence of winds carrying moisture and solids from the broad areas of surrounding sea. That solids from the sea are in fact returned to the land has been shown by Gibbs (39) who found that as much as 350 lb. per acre of salt is deposited in a year by rain at places within a few miles of the sea and 112 lb. per acre is so deposited at a point 30 miles inland. It is not unreasonable to suppose that an appreciable quantity of iodine would also be derived from the same source.

The first account of goitre in domestic stock in New Zealand was written by Gilruth in 1901 (40). Calves and lambs were reported to be suffering from enlarged thyroid glands and the occurrence of the disease was the more remarkable since the farm on which it occurred had been occupied for 16 years without any previous record of similar trouble. Such a report might well be written at the present day as sometimes even now a heavy incidence of goitre in young stock is found, frequently for the first time, on land that has been farmed in much the same manner for as long as 50 years. However, the failure of farmers

to report goitre may not indicate faithfully the absence of minor lesions, since cases have been seen of moderate enlargement of the thyroid gland in sheep which had all the outward appearances of excellent health.

Cattle, sheep and horses have been affected by iodine deficiency in New Zealand. The young may be born dead, hairless and with enlarged thyroids, or may die within a few days. In some flocks of sheep up to 50 per cent. of lambs have been lost from this cause.

Treatment of affected animals with iodine has in general proved successful. For example, young goitrous lambs which survive the first 3 days can usually be reared if dosed with solutions of iodine or potassium iodide; and regression of thyroid size in adults and prevention of further cases in young has been claimed as a result of supply of iodized licks.

The disease has usually occurred on river flats or alluvial soils but no thorough examination of affected soil types has yet been made. This is now in the process of being done at Wallaceville by detailed mapping of all areas of known iodine deficiency amongst animals for later comparison with soil maps. A chemical survey conducted between 1930 and 1938 showed that enlarged thyroids of low iodine content in lambs sent to Meat Works originated from parts of Wellington, Nelson, Marlborough, Westland, Canterbury and Otago Provinces (41).

In respect to etiology it is generally agreed that low dietary iodine is at least one important cause. In New Zealand Hopkirk, Dayus, Simpson and Grimmett (42) found low soil and pasture iodine associated with one outbreak in lambs; Hercus, Benson and Carter (43) make the same claim concerning the human disease, and much overseas work is in the same strain. Nevertheless the irregularity of occurrence from year to year on the same land suggests that low soil and pasture iodine may not be the only cause of simple goitre. Shore and Andrew (44) and Orr (45) have shown that in human endemic goitre the dietary iodine is not always low. The possibility of positive goitrogenic factors such as have been found, for example in cabbage (46) and in brassic seeds (47), (48), should be more thoroughly investigated in connection with endemic goitre in animals. This investigation must start from the field and take into account such features as soil type, pastures and crops and their management as well as variation in environmental factors such as climate.

Until a more thorough understanding of etiology suggests some other treatment the method of control will remain the provision of additional dietary iodine; for this purpose the most convenient form is in mineral licks. Accurate assessment of the efficacy of this procedure is beset by many difficulties. Some goitrous sheep refuse iodized licks in spite of the use of suitable lures; the disease may not recur in successive years on the same property; and the stability of potassium iodide which is the salt

usually employed, is low when it is exposed in licks so that stock may not get iodine even if they eat the lick. No control can be exercised over the first two variables, but it is very necessary to discover some form of iodine that can be employed in licks and which will contain iodine readily available to the animal, yet be resistant to oxidation, leaching and other effects of exposure. Still further it is essential that this iodine containing compound be inexpensive. Some work has already been done in this field and attempts have been made to protect KI in licks by coating with calcium stearate (49), by including thiosulphate, or by making licks slightly alkaline. Simple iodinated proteins not active as thyroproteins or other stable organic compounds of iodine might also be suitable.

The use of licks is always a hazardous method of supplying minerals to stock and application of the missing element to the pasture as a topdressing is preferable. This has not yet proved practicable with iodine on account of cost and because many factors such as soil pH and pasture species (50) modify the uptake of iodine by plants. A solution to these problems would be of extreme value. One possible line of experiment is topdressing trials with some of the newer resin exchange materials with iodine absorbed on to them. Such materials may give up iodine slowly over a long period and thus prove suitable and economic for topdressing.

Other Elements

The trace element deficiencies already dealt with are the only ones of direct importance to the health of animals. Others, most of which affect plants only will be mentioned very briefly.

Fluorine.

The fluorine content of most river waters in the North (51) and the South Islands (52) is less than 0.5 parts per million and is, therefore, below the level that is commonly regarded as necessary in drinking water to provide for optimal formation of tooth enamel. This deficiency may have some effect in rendering the human population susceptible to dental caries. There has been no direct association of dental abnormalities in animals with the low fluorine of water.

Molybdenum.

A soil deficiency of molybdenum has been found to be the cause of whiptail in cauliflowers (53) and this disease can be prevented by the application of ammonium molybdate as a fertilizer to the soil (54). The increased growth of pasture that results from molybdenum topdressing in certain localities has also been taken as an indication that a deficiency exists.

Chemical determination of the total molybdenum content of soil is not a satisfactory measure of molybdenum status because

of the great difference of availability of this element in different soils and under different conditions of pH. Davies (55) has examined a number of laboratory methods for measuring availability and has reached the tentative conclusion that Tamm's oxalate extractant gives the most reliable measure. Observations on Okaihau gravelly silt loam illustrate the importance of availability. This soil contains over 9 parts per million total molybdenum and 0.07 p.p.m. soluble in oxalate solution. The low availability thus indicated is confirmed by an increased growth of pasture, which results from topdressing with molybdate. Other soils with much less total molybdenum but with a higher oxalate soluble fraction show no response to molybdenum fertilizers. Availability of molybdenum is increased by liming and it is not unlikely in some cases that apparent response to lime may be due in fact to increase of available molybdenum.

Manganese.

No deficiency of manganese has been observed. On the contrary there have been observations which point to some soils having an excess of active manganese that retards plant growth. The application of sufficient lime reduces the available manganese to a level that is tolerated by plants. An example of this phenomenon is Davies' (55) work on Ngaio silt loam. In pot experiments he found that the untreated soil supported only very limited growth of subterranean clover. The herbage that did grow contained a very high concentration of manganese. Limed pots grew much more clover with a very much smaller content of manganese.

Boron.

Boron deficiency causes brown heart of swedes (56) and internal cork of apples (57). These diseases are of considerable importance in New Zealand and are controlled by application of boron as a fertilizer. Some soils are naturally deficient in boron; in others, especially those on the threshold of boron sufficiency, the deficiency may be induced by heavy applications of agricultural lime.

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BANQUET AND BUSINESS MEETING

The Tenth Annual Banquet was held at the Haven Hotel on the evening of June 22, 1950. This was a particularly auspicious occasion because of the impending election of ten Honorary Life Members to the Society of a world wide selection in view of their contributions to Soil Science and to Agriculture. The election of an additional member from the field of medicine to be known as our "Country Doctor" was of particular interest and not intended to merely signify our recognition of the growing importance of the relationship between soil science and health, of man and beast alike, but also to call the attention of the State and of the Nation to one of Florida's oldest and most faithful practitioners who, himself, has been conscious of this important relationship for many, many years. In fact he always sought to enlarge his knowledge in this field through the years and to use it as a veritable cornerstone for his medical practice.

The Guest Speaker for the occasion was Dr. Edward MacArthur Redding, Director of Research, Charles F. Kettering Foundation, Dayton, Ohio. His subject was "Photosynthesis—A Link Between the Sun and the Soil." Dr. Redding's lecture as well as the introduction of the Honorary Members, will be found at the front of this volume. The presentation of these nominations was made by the Secretary with the exception of Dr. Charles F. Kettering who was introduced by Dr. Redding and Dr. John G. DuPuis, M.D. whose life work was very ably reviewed by Mr. Nixon Smiley of the Miami Herald.

BUSINESS MEETING

The Business meeting was of necessity very short and consisted of little more than the report of the Nominating Committee, Dr. E. L. Spencer, Chairman and of the Resolutions Committee, Mr. Luther Jones, Chairman. The former in reporting on the action of his committee, which included Mr. F. E. Boyd and Mr. J. R. Henderson, nominated Dr. I. L. Wander for Vice-President, this being the only elective position open each year. In the absence of any nominations from the floor upon call from the Chairman, the usual motion was made by Dr. G. M. Volk and seconded by Mr. R. N. Edwards, and carried, that the Secretary be instructed to cast a unanimous ballot for the nominee. The report of the Resolutions Committee is to be found on the following page.

The report of the Secretary-Treasurer and of the Editor were oral and brief. In the matter of dedication of Proceedings Volume X it was decided that this should be to the ten Honorary Life Members who were formally received into the Society during the evening and who, along with Dr. DuPuis, have so graciously accepted this recognition which the Society has extended.

Meeting of the Executive Committee

The only matters taken up at a brief meeting of the Executive Committee were the appointment of a Secretary-Treasurer, R. V. Allison, Belle Glade, and a discussion of the feasibility of including a well-developed symposium on fiber crops in South Florida for inclusion in the program of the next annual meeting to be held in West Palm Beach. The plan was generally approved and the further thought extended that it would be a good idea to include a field trip on this same subject if satisfactory arrangements could be made to that end.

RESOLUTION OF SYMPATHY

Soil Science Society of Florida

Whereas, death has taken from our rolls during the year 1950 the following esteemed members of the Society whose sincere and constructive interest in all aspects of the work will make their absence keenly felt for a long time to come,

Now Therefore, Be It Resolved, that this expression of sorrow over this great loss and of sympathy to the immediate families of the deceased be spread upon the records of this Society and a copy of same be sent to the closest member of the family of each.

Dr. Oskar Baudisch
Saratoga Springs, N.Y.

Mr. Daniel W. Beardsley, Sr.
Clewiston, Fla.

Dr. M. A. Brannon
Gainesville, Fla.

Mr. R. O. Couch
Melbourne, Fla.

Mr. G. Milton Fisher
Westboro, Mass.

Mr. Charles T. Fuchs
South Miami, Fla.

By the Resolutions Committee,

Luther Jones, Chairman.

DR. W. T. FORSEE, JR.

RETIRING OFFICERS OF THE SOCIETY

(1950)

W. T. FORSEE, JR. .... President

RICHARD A. CARRIGAN .... Vice President

HORACE A. BESTOR .... Mbr. Exec. Committee

R. V. ALLISON .... Secretary-Treasurer

APPENDIX

●

The Minor or Trace Elements in Soils, Plants and Animals*

W. O. ROBINSON**

This leaflet has been prepared as a reply to numerous requests for information as to what chemical elements are needed for normal, healthy plant and animal development, how to restore "trace minerals" to the soil, and similar inquiries.

The whole subject is now in a state of flux due largely to the lack of accurate, fundamental knowledge of the quantities present and essentiality of the various minor elements in soils, plants, and animals. The availability of these elements to the plant varies a great deal with the chemical and mineral combinations and soil conditions in which they occur. The problem is still further complicated by our lack of knowledge of the complex organic compounds such as enzymes, vitamins, and biotics, in which these elements function in the chemical metabolism of the plant.

The minor or trace elements have acquired the following meaning: They are present in very small quantities in the plant and animal, generally less than 500 parts per million on the dry weight basis. They are generally, but not necessarily, essential to the plant or animal, though in some cases they may be poisonous to those organisms. The minor elements are commonly removed from the soil by plants in greater quantities than many soils can supply for considerable periods of time, or are required by the animal in quantities greater than supplied by the plant grown under some soil conditions.

The more important minor elements are iron, boron, manganese, copper, zinc, cobalt, iodine, selenium, and molybdenum. Some of these are not necessary for plants but are required by animals. Iodine and cobalt are such elements. Molybdenum appears to be necessary in very small quantities for plants but not necessary for animals, in fact it is toxic to ruminants if present in forage in quantities exceeding 6-10 parts per million. Both molybdenum and selenium are taken up in considerable quantities by plants and have very little effect on the plants, though the selenium in the plant is toxic or even lethal to animals.

There is nothing mysterious about the essentiality of the chemical elements to plants and animals. It is the natural out-

*—A mimeographed release prepared shortly before the Winter Haven meetings.

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growth of the evolution of the plant and animal forms we now have. They can be considered as very delicately adjusted laboratories having to make use of the elements in their environment. The order of abundance of the elements seems to be one requirement of essentiality but the essential element also has to perform some useful chemical reaction.

Through the geologic ages during which evolution has taken place, the organisms which could best adapt their chemistry to make use of the raw materials, in this case the chemical elements, and the source of energy, the sun, have survived. The question as to whether an element is essential or not depends upon whether this element has been useful to the organism in surviving through the ages. Changes have taken place in plant and animal environment, temperature changes, and changes in the composition of the atmosphere.

The bodies of plants and animals are largely composed of water. The chemistry of metabolism is a water chemistry in which varying degrees of solubility are most important. It is supposed that animal life developed in the sea where the organism had a great variety of elements at its disposal. Animal digestion is primarily an acid digestion dependent upon hydrochloric acid derived from sodium chloride, the most prominent salt in sea water.

At this point it is interesting to consider the abundance of the elements on the earth's surface. This has been calculated for a shell 10 miles deep including the atmosphere and the oceans—This order of abundance is:

> (1) Oxygen 49.10 percent, (2) Silicon 26.00, (3) Aluminum 7.45, (4) Iron 4.20, (5) Calcium 3.25, (6) Sodium 2.40, (7) Magnesium 2.35, (8) Potassium 2.35, (9) Hydrogen 1.00, (10) Titanium 0.61, (11) Carbon 0.35, (12) Chlorine 0.20, (13) Phosphorus 0.12, (14) Sulfur 0.10, (15) Manganese 0.10, (16) Fluorine 0.08, (17) Barium 0.05, (18) Nitrogen 0.04, (19) Strontium 0.035, (20) Chromium 0.03, (21) Zirconium 0.025, (22) Vanadium 0.02, (23) Nickel 0.02, (24) Zinc 0.02, (25) Boron 0.01, (26) Copper 0.01, . . . (32) Cobalt 0.002, . . . (38) Molybdenum 0.001, . . . (56) Iodine 0.0001, . . . (62) Selenium 0.00008.

The order of abundance of the elements in plants and animals may be approximated:

> (1) Oxygen, (2) Carbon, (3) Hydrogen, (4) Nitrogen, (5) Calcium, (6) Potassium, (7) Magnesium, (8) Phosphorus, (9) Sulfur, (10) Iron, (11) Manganese, (12) Boron, (13) Zinc, (14) Copper, (15) Chlorine, (16) Sodium, (17) Fluorine, (18) Iodine, (19) Cobalt.

The most abundant elements in plants are the atmospheric elements from which organic matter is largely metabolized. They

make up sugars, starches, cellulose, fats, etc., and the bulk of proteins and more complex organic substances. The atmosphere is the main environment of most plants and animals, and water organisms depend upon dissolved oxygen for energy.

To carry on the side chemical reactions that take place through photosynthesis to metabolism, the plant has made use of the most abundant elements at its disposal that would perform the necessary chemical reactions. In the average soil solution and river water, calcium is the most abundant alkaline element and next to the main atmospheric elements it is the most abundant element in plants. Part of the function of calcium is to remove a side product of photosynthesis, oxalic acid, which it does by precipitating the insoluble calcium oxalate.

The more abundant elements that are not useful to plants and animals are the very insoluble elements in the combinations in which they occur. Thus, of the first fifteen in order of abundance, only three, silicon, aluminum and titanium, are not essential to the majority of organisms, at least in anything more than traces.

More detailed descriptions of the minor elements in plants and animals follow:

Iron

Iron has long been recognized as essential for healthy plant development. It is directly connected with the functioning of the chlorophyll in plants and the red blood corpuscles in the animal. In the leaves of healthy plants iron will average a few hundreths of one percent (dry weight basis), the quantity never varying greatly.

Although there is an abundance of iron in nearly all soils, the soluble or exchangeable iron in calcereous or other soils around the neutral point may be so low that plants are unable to absorb enough for healthy growth. The solubility of iron in the soil is governed by the reaction of the soil, the element being comparatively soluble in very acid soils and also by the prevalence of reducing conditions. The submerged soil conditions that occur in very wet weather are favorable for the solution and transportation of iron in the soil solution and in extreme cases the concentration of iron may exceed the toxic limit.

The addition of any reducing organic matter such as crop residues, stable manure, or compost increases the supply of available iron in the soil. The iron is temporarily reduced and made soluble and the complex ions formed with the organic matter hold the iron, even after oxidization, in solution at pH concentrations that would otherwise precipitate the insoluble ferric hydroxide. Plants are sometimes sprayed with solutions of ferrous sulphate to cure iron deficiency. In Hawaii, the pineapple crop is sometimes sprayed four times a year with an 8 percent solution of ferrous sulphate.

Boron

Boron, from the standpoint of agriculture, is unique among the chemical elements in that very small quantities are necessary for the growth of many, if not all plants, and only slightly higher concentrations cause injury. With a number of plants the range between these two levels is only a few parts per million.

Boron is present in quantities up to 200 parts per million in all normal, healthy plants. Orchard-grown citrus leaves suffering from boron injury may contain in excess of 5 times as much. Soils contain from 3 to 90 parts per million total boron. Only a small portion of this boron is water soluble. In New Jersey one half part per million of water soluble boron in the soil is considered ample.

Many crops show boron deficiencies. The heart and dry rot of sugar beets, internal cork of apples, browning and hollow stem of cauliflower, yellows of alfalfa, cracked stem of celery, top rot of tobacco and brown or watery heart of turnips are boron deficiency diseases.

Alfalfa yellows and failure of alfalfa to seed can be remedied by applying 20 to 60 pounds of borax to the acre. For tobacco no more than 10 pounds per acre should be used. For boron deficiencies in other crops varying quantities are used depending on the texture and composition of the soil. Special fertilizers for alfalfa contain 60 pounds of borax to the ton; this not only remedies alfalfa yellows but greatly increases the yield of seeds.

The availability of boron is much less in calcareous than in acid soils. In some calcareous soils the soil application of borax is not effective. It is necessary to spray the plants. Three pounds of borax in 100 gallons of water make a suitable spray.

As before mentioned boron is quite toxic and much injury has resulted in the past from using potash salts which contained boron in harmful amounts. Borax even at the rate of 30 pounds per acre may cause injury to sensitive crops in very dry seasons on sandy soils.

Manganese

Manganese is a common constituent of soils and plants, the quantities present in both varying greatly. In many soils and plants manganese is a major element. Certain Hawaiian soils contain as much as 15 percent Manganous oxide, and some soils in the United States contain over 3 percent. Some plant leaves, particularly the forage legumes contain as little as a few thousandths of one percent, and a number of tree leaves growing on very acid soil contain over 0.5 percent.

Some soils contain only a very small quantity of manganese. Others containing much manganese may have it in an unavailable form such as the very insoluble dioxide. This latter condition obtains in calcareous and other alkaline soils, and in any

soil immediately after heavy liming. There is no correlation between the total manganese in soils and in plants growing on these soils. The availability is governed rather by the acidity and reducing action of the soil than by the quantity present. The exchangeable manganese in forest leafmold commonly equals and sometimes exceeds the exchangeable calcium.

The manganese in soils containing organic matter becomes very soluble when these soils are submerged for relatively short periods. Under these conditions the concentration of soluble manganese exceeds the limits that have been found to be tolerated by plants. On acid soils, injury to tobacco, pineapples, beans and other crops by excessive quantities of manganese has been noted.

There are a number of deficiency diseases due to lack of available manganese in the soil. These are chlorosis of tomatoes and other plants on highly calcareous soils. The "marsh spot" of peas and "gray speck" of oats occurs on organic soils in the British Isles and Northeastern Europe.

Manganese deficiency has been noticed in animals. It causes "slip tendon" or perosis in chickens, also low hatchability of eggs. Low manganese in feeds also causes lameness in pigs and sterility in bovines.

The quantity of manganese that must be supplied on soils to correct the shortage may vary, but additions of 25 to 50 pounds of manganous sulphate per acre have resulted in remarkable increases in crop yield on certain soils.

Copper

Copper is 26th in order of abundance in the earth's crust, the average being 100 parts per million. Soils average considerably lower than this. Leaves of green plants seldom contain less than 5 p.p.m. or more than 20 p.p.m. Copper is said to be concentrated in the seeds of plants. In the corn seed. the germ contains 20 p.p.m. and the endosperm 0.5 p.p.m.

Copper deficiency in vegetables is confined to those grown on high organic soils. In some of the rich organic soils in the Everglades of Florida lettuce, celery, and other vegetables cannot be grown without the addition of from 25 to 50 pounds of copper sulphate per acre. A disease of citrus, pears, prunes, and other fruits, exanthama or die back, and also the reclamation disease are caused by a deficiency of copper.

In the animal, copper is necessary for the utilization of iron in the formation of haemoglobin. Piglet anemia and sway back of lambs are due to copper deficiency. "Stringy" wool of sheep (Australia), "Scouring disease" (Holland), "Licking disease" of ruminants (Europe), "Coast disease" of grazing animals (Australia) and "Salt sick" of cattle (Florida) are due to a dual deficiency of copper and cobalt.

Zinc

Zinc is the 24th element in order of abundance in the earth's crust. It is present there at the average of 200 p.p.m. Soils vary a great deal in zinc content ranging from a little less than 5 p.p.m. to over 200 in soils of considerable extent. The range in plants is much greater; from 5 to over 5000 p.p.m. It is odd that the plant can accumulate so much zinc without showing any toxic effect.

Plants suffer a number of deficiency diseases due to lack of available zinc. They are "Little Leaf," or "Rosette" of apples, pecans, vines, and stone fruit; "Mottle Leaf" of citrus, "Yellows" of walnut, "Bronzing" of tung trees, and "White Bud" of corn. Animals appear to get an abundance of zinc in the plants they consume.

Zinc forms about 0.3 percent of carbonic anhydrase, a respiratory enzyme found in both animals and plants.

Zinc sulphate is applied as a spray or directly to the soil to correct deficiency diseases. Up to 25 or even 50 pounds per acre have been used and in certain calcareous soils as much as 200 pounds per large pecan tree have given economic increase in crop yields.

Cobalt

Cobalt is of interest because it is necessary especially for cattle and sheep. Only about a milligram per day is necessary even for a large animal. For over two centuries it has been known that certain pastures in the British Isles produced "pining" in cattle and sheep. Long ago this disease was correctly ascribed to the forage but not until nearly 20 years ago was the real cause known. It is a cobalt deficiency disease. Cobalt deficiencies are found in a number of places in the United States.

Cobalt does not appear to be essential to plants. However, it is necessary for cattle foods to contain as much as 0.08 p.p.m. for complete animal health. Cobalt is given as a mineral supplement or drench. In New Zealand it is used at the rate of two pounds of cobalt sulphate per acre applied with superphosphate.

Iodine

Iodine deficiency is the classical animal deficiency disease. And unlike the rest of the minor elements, the deficiency was first found in humans. Later it has been traced to various domestic animals. Lack of sufficient iodine in plants and water causes goiter. Iodine does not appear essential to plants but is taken up by them in amounts ranging from 20 to 200 parts per billion. These are average quantities for various plants used as foods. Occasionally plants are lower and some very much higher.

The goiter belts are generally on coarse, gravelly, sandy soils having little clay or organic matter, or in areas profoundly leached by melting snow. In the earth's crust iodine is 56th in order of abundance, or one part per million. It is the least abundant element which has been definitely proven essential to animals.

Like salt, sodium chloride, it has been found practical to supply this element artificially. The need for salt was intuitively shown by the craving for salt before the dawn of history, but it took years of patient chemical research to connect goiter and cretanism with iodine deficiency.

Molybdenum

Molybdenum is of interest because minute quantities are required for nitrogen fixing bacteria, and in some places pasture plants take up enough of this element to be definitely toxic to cattle and sheep.

In some places in Australia economic responses in yields of subterranean clover have been realized by the application of as little as one ounce of molybdenum per acre. Elsewhere molybdenum deficiencies in soils in the field have not been observed, though some soils have been found molybdenum deficient in greenhouse tests.

In the earth's crust molybdenum is 38th in order of abundance, the average being 10 p.p.m. In over 200 representative American soils molybdenum averages 2.6 p.p.m., 85% of these soils range between 1 and 4 p.p.m. In plants and plant parts the range is from less than 0.1 to over 400 p.p.m., though forage plants seldom exceed 10 p.p.m.

In some parts of the British Isles and in some parts of California and Florida the vegetation has been found to exceed 10 p.p.m. molybdenum. Cattle fed on such pasturage become unthrifty and sometimes die. Molybdenosis in cattle is not only dependent upon the quantity of molybdenum in the plant but also upon the copper content, for these two elements appear to be antagonistic in the ruminant. Molybdenosis has been cured by feeding the animal 1 to 2 grams copper sulphate daily.

The quantities of molybdenum that plants will take up is greatly increased by making the soil alkaline with calcium carbonate. It is of low availability in acid soils. In "black alkali" soils molybdenum availability would be very high. This property of molybdenum, (also selenium), is quite the opposite from iron, manganese, zinc, cobalt and copper, the availabilities of which are decreased by overliming.

Phosphate rock, from which superphosphate is made, generally contains molybdenum, and some Florida and Western phosphates contain as much as 50 to 200 p.p.m. Superphosphate makes up the bulk of mixed fertilizers, and it is believed that no soil deficiencies of molybdenum will occur on soils that are

fertilized with commercial fertilizer. On the other hand, no fears are anticipated that the use of superphosphate will cause molybdenum toxicity in cattle for superphosphate applications reduce rather than increase the molybdenum content of vegetation.

Selenium

This element is of interest because of its extremely poisonous properties. Enough of it is taken up by certain plants to be lethal to animals eating even small portions. Such poisonous plants appear perfectly healthy. They have adapted their chemistry to use selenium; it may even be essential to their development.

Selenium is even somewhat rarer than iodine. It is, however, concentrated under some conditions of soil development. When certain cretaceous shales form soil under semi-arid conditions, selenium becomes available to plants. All soils contain some selenium, but it is only under semi-arid conditions, in alkaline soils, in presence of calcium carbonates and sulphates that plants take up enough to be poisonous. Highly ferruginous soils of Hawaii, Puerto Rico, and Southern Texas may contain as much as 10 p.p.m. selenium and not produce toxic vegetation whereas soils formed from Pierre Shales in South Dakota, Wyoming and other nearby States may contain only 0.5 p.p.m. and produce lethal vegetation.

Sprays containing selenium are very effective in controlling red spider. Sodium selenate is used in low concentrations in greenhouse soils to kill aphids, red spiders, and foliar nematodes. Enough of the element is taken up by the plant to kill these insect pests. Food plants raised on soil so treated may be quite poisonous. Great care should be exercised in using selenium sprays on plants and sodium selenate on the soil.

Other Elements

Considerable fluorine is let loose into the atmosphere by industrial processes such as the manufacture of aluminum, superphosphate, bricks, glass, steel, high octane gas and some chemicals. This gas is quite toxic to vegetation, and to cattle and sheep feeding on fluorine contaminated vegetation. Fluorine is not taken up from normal soils by the plant in injurious quantities. Fluorine in quantities of about 1 p.p.m. in drinking water seems to exert a beneficial effect on human teeth.

Barium and strontium are present in more than traces in most plants. Barium may reach as high as 0.2 percent in some leaves. Those elements seem to have little or no effect on plant and animal growth in the quantities they occur in vegetation. Barium carbonate is quite poisonous to animals.

The rare earths as a group appear to act as one element biochemically. They are present in the earth's crust as 0.018 percent

and the group would be 25th in order of abundance. They form relatively insoluble oxalates, and may function as calcium in plant growth. Hickory leaves may contain as high as 2000 p.p.m. rare earths. These elements appear to be present in small quantities in all plants. Rare earths presumably concentrate in the skeletal structures of animals. Very little is known about the physiological reaction of the rare earths on animals.

Sodium, chlorine, silicon and possibly aluminum form a group of elements, which although not absolutely essential, are definitely beneficial to some plants under some conditions. Silica is especially high in the grasses.

Through further research it may develop that other elements may be essential to plant or animal life even when present in such very small, or smaller, quantities than iodine. Given an abundance of sample and a sensitive and exhaustive method of chemical analysis, it is believed that nearly all the elements, except perhaps the rare gases, could be shown to be present in plants and animals. Silver, lead, tin, gallium, germanium, and even gold have been found in many plants. It is not known whether their presence is merely accidental or if they serve some useful purpose.

The various State Experiment Stations are familiar with the minor element requirements of plants and animals. These requirements naturally vary with local conditions and the County Agricultural Agent and State Experiment Station should always be consulted.

THE SOIL SCIENCE SOCIETY OF FLORIDA

PROCEEDINGS
VOLUME XI
1951

Eleventh Annual Meeting of the Society
George Washington Hotel
West Palm Beach
October 29 and 30
Field Inspection Trip, Everglades Area
October 31, 1951

OFFICERS OF THE SOCIETY
1952

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NATHAN GAMMON, JR. .... Vice President
W. T. FORSEE, JR. .... Member Executive Committee
R. V. ALLISON .... Secretary-Treasurer

Retiring Officers listed on page 189.

ACKNOWLEDGMENTS

The Executive Committee in behalf of the entire membership of the Society desires to take this opportunity to thank the officials and the staff of the George Washington Hotel for their splendid hospitality and tireless efforts in making the meetings a success also the officials of the Central and Southern Florida Flood Control District and of the Florida State Geological Survey Tallahassee and of the Jacksonville Office of the Corps of Engineers Department of the Army for their fine assistance with the Panel Discussion of Water Conservation also the officials of the Everglades Experiment Station of Newport Industries Inc and of American Kenaf and Ramie Corporation for their splendid help in connection with the fiber crop field trip and with the first meeting of the Committee set up by the U S Department of Agriculture to develop and define a system of marketing grades for kenaf the proposed soft fiber substitute for jute to be grown in the Western Hemisphere

We wish also to express our particular appreciation to Mr Walter R Guthrie of the Lehigh Spinning Company Allentown Pa for the generous amount of time he gave us and the fine part he took in the program and to the following officials from Washington D C and elsewhere for the special effort they made to be with us Dr Arthur G Peterson Chief Textile Forest and Agricultural Products Division Office of Materials Munitions Board Dr Charles W Schoffstall Chief Fibers Branch Textile Division National Production Authority Mr E D Bell Deputy Director Cotton Branch Production and Marketing Administration U S D A and his Associates Mr Wilson C Tucker and Mr H C Slade and Messrs George R Boyd and Elton G Nelson Bureau Plant Industry Soils and Agr Engineering U S D A , likewise to Mr N N Mayo representing the Commissioner of Agriculture Honorable Nathan Mayo Dr Herman Gunter State Geologist from Tallahassee Col A G Matthews Chief Engineer Div Water Surveys and Research State Board of Conservation Tallahassee Dr Wm L Lett Secretary National Cotton Council Memphis, Mr George F Quimby Secretary Treasurer of Soft Fiber Manufacturers Institute New York City Col George D Green, President Southern States Bag Company Jacksonville and to Mr Alexander Low N A Rep Indian Jute Mills Assoc Inc New York City

Finally, we want to express our sincere pleasure for having had with us during these meetings a number of foreign members and friends notably a very fine delegation from Cuba among which Mr Jose A Perez represented the Minister of Agriculture Mr Luis A Sanjenis Second V P and Ing Manuel Suarez Carreño Treasurer respectively of the Asociacion Nacional de Cosecheros de Kenaf de Cuba were this organization's representatives, and Ing Julian B Acuña represented Banco de Fomento e Industrial de Cuba Messrs Federico Poey and Joe E Walker of Havana and Eduardo Lopez of Guanabacoa Cuba also were in attendance and Mr Duane V Clair of the Office of Foreign Agricultural Relations U S D A Washington D C and his co workers from Pakistan Messrs Wadihul Islam MD T Hussain and A F MD Hafizur Rahman It is of course a particular pleasure to record the attendance of our good friend and fine cooperator in the fiber work Mr R A Colver of Sydney Australia and Rabaul New Guinea

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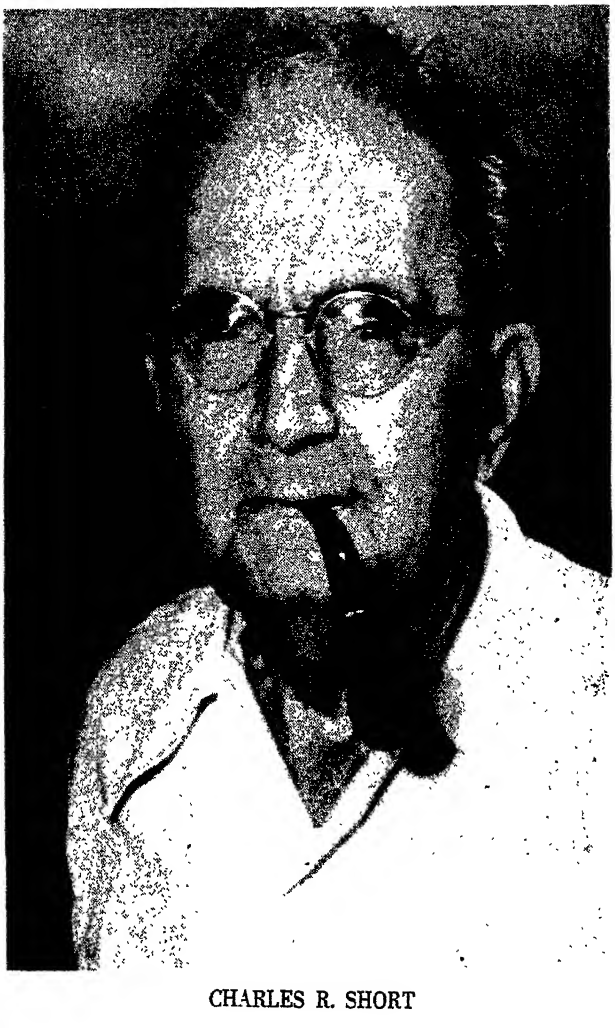

CHARLES R. SHORT

DEDICATION

CHARLES R. SHORT

Charles R. Short was born in London, Ontario, Canada in 1871, where he attended school and then served as an apprentice machinist and tool maker. He first entered the United States in 1899 and worked in Detroit, Michigan; Cleveland, Ohio; Erie, Pennsylvania and New Haven, Connecticut. Returning to London, Canada in 1891, he married Mary Adaline Clark. To them four children were born.

From 1891 to 1906 Mr. Short was Chief Engineer, Motor Division, Canada Cycle and Motor Company, located at Toronto Junction, Ontario, Canada. A practical aluminum body ice skate was developed during this period. Following his return to the United States in 1906 he was Chief Engineer, Standard Gas and Electric Company, Philadelphia, Pennsylvania until 1910. During this time he developed the auto motor electric starter and equipped test cars for Cadillac, Peerless, Pierce Arrow and Stevens Doyrea.

From 1910 to 1912 he was Electrical Engineer for Packard Electric Motor Company, St. Catherines, Ontario, Canada. While employed there he developed the auto electric starter for the Canada Cycle and Motor Company, Toronto.

Returning to Detroit in 1912 he formed the Short and Wilson Tool and Machine Company, and continued in this work until 1916 when he became Chief Engineer, Northway Motor Division, General Motors. He continued in this position until 1922 when he was made Chief Engineer, General Motors Research in which position he remained until 1931 when he retired. During these years there was developed, among innumerable other improvements to automotive equipment in the General Motors field, the "V"-Belt.

Following his retirement in 1931 from General Motors Research Mr. Short moved to Clermont, Lake County, Florida, where he developed the Florida Industrial Laboratory. Since the establishment of this laboratory there has been developed in it a dehydrating machine for the preparation of sawgrass peat for market; many projects in connection with the local diatomite deposits including a remarkable "all-weather", salt shaker; a hyacinth cutter for the U. S. Engineer Corps, Jacksonville and decorticating and degumming machines for bast fibers. He also developed a Citrus Research Grove to assist with the solution of some of the nutritional problems of this important industry in Florida at about the time they had arrived at their most critical level in the middle to late thirties; and he is president of the Citizens Bank of Clermont.

It is regrettable that Mr. Short's attendance upon these meetings was prevented by the recurrence of an unfortunate illness which has given him considerable trouble during recent years and which required hospitalization at this very time and a serious operation. Fortunately, he had again quite fully recovered by the time this Proceedings was ready for the press and was back again in the shop as active as ever on the development of equipment and processes for the decortication and degumming of bast-fibered crops (ramie and kenaf), a project we are inclined to believe has been the "apple of his eye" since about 1944.

Miss Bernice Montgomery standing beside an exhibit of all ramie fabrics which she arranged at the time of the meeting. The small parasol which she is holding is of Japanese design and construction, the cover being of course RAMIE.

RAMIE CULTURE IN THE FAR EAST

BERNICE MONTGOMERY

This Chinese poem from the Book of Odes contains the oldest known reference to the fiber which we now call ramie. The poem is at least 2,500 years old, perhaps older. The poet tells of a beautiful lady and compares her to the water in the moat at the East Gate of the city. In order to describe how shining and clear the water is he says it is fit for steeping ramie. It is interesting to note that the character denoting the fiber "ramie" is similar to that used for silk. In other words the above character for ramie represents a beautiful lustrous fabric made of fiber from plants of the genus Boehmeria; the character for silk represents a beautiful lustrous fabric made from fiber spun by the silk worm.

東門之池可以漚麻
彼美淑姬可與晤歌
東門之池可以漚紵
彼美淑姬可與晤語

This Poem in Ancient Chinese makes the first known reference to Ramie in the literature of the world. Very kindly reproduced from the original by Joseph En-pao Wang, Division of Orientalia, Library of Congress, Washington.

Many people in America think of ramie as being principally Chinese in origin. Actually, according to Oriental legend, ramie plants first grew and the fiber was first used on the southeastern slopes and foothills of the Himalayas, especially down through the area which is now Malay and part of Indonesia. The word "ramie" is the Anglicized form of the ancient Malayan word for the plant and its fiber.

People on the Indo-Pakistan subcontinent have also been growing and processing ramie fiber for a long time. It is quite possible that the ramie fabrics found on some of the Egyptian mummies of the pre-dynastic period (3300 B. C. to 5000 B. C.) were imported by the Egyptians from India. Ramie fabrics are mentioned in ancient Vedic literature. Reference to ramie is found in the drama "Sacantala" by Kalidassa, generally supposed to have been written about 100 B.C.

Much of the ramie fiber used in the Far Eastern areas is obtained from plants growing in a wild state. Methods of preparation vary widely, though all involve essentially the same principles. Everyone will recall reading varying descriptions of these processes, each description purporting to be the correct one. Actually it is one of those happy situations where practically every one is right. Lack of transportation and communication in these areas have resulted in each small area developing

Marketing Consultant, Fifth Avenue Hotel, New York City.

its own way of processing ramie. In most cases this way has been maintained without change for many generations.

Basically, the processing involves first, removal of bark with fiber attached, by peeling; stalks may or may not be soaked in water before this peeling takes place. In some areas the peeled bark, with fiber attached, is dried and later soaked in water, hot or cold, fresh or salt, before the fiber is freed from the bark. This latter method is generally used in the northern regions where the winter season with little farm activity allows time for processing of ramie fiber during this period of the year.

Instruments used to free the fiber from the bark, by scraping, range from clam shells to specially prepared pieces of bamboo and iron knives, depending on local customs and equipment available. A protector of some sort is wrapped around the thumb, the scraping instrument held in the palm of the hand and the fiber then drawn between the edge of the scraper and the thumb. The amount of scraping done, that is, the degree of separation of the fiber from the bark and from the gums and waxes, depends largely upon the intended end use of the fiber. Obviously, if the fiber is to be made into very fine yarns, a great deal of scraping will be required, that intended for coarse yarns does not require much scraping.

China for many years has grown most of the world's supply of commercial ramie fiber, the total production averaging about 75,000 tons annually, pre-World War II. This country's exports averaged about 25,000 tons annually during the same period. Methods of cultivation and processing used in China are generally primitive. Cultivation and harvesting are done with hand labor. Fiber removal is also done by hand, though in a very few instances a small machine decorticator may be used. Degumming is done by alternate soaking and hand scraping; in some areas the yarn or fabric is also boiled in a weak solution of caustic soda, which removes some of the gum and acts as a bleaching agent.

Chinese ramie fiber intended for commercial export is often bleached with charcoal or sulfur fumes after it has been separated from the bark of the plant. This is the so-called "white" ramie of commerce. The terms "white" and "green" used in this connection should not be confused with the terms "white bark" and "green bark" used in connection with ramie plants grown in the Far East. The last two terms apply to varieties of *Boehmeria nivea* and not to the decorticated fiber.

Ramie has apparently been grown in the Philippines since prehistoric times. It was first cultivated on a commercial scale during the 1930's in the southern island of Mindanao, especially on the land owned by Japanese capital. Production was, of course, disrupted during World War II. Post-war production has been slow in resumption because channels of trade have been re-established only slowly. It is expected, however, on the basis of present plantings and plans, that ramie fiber protion in the Philippines Islands will increase markedly in the near future.

Utilization of ramie is also found on most of the islands of the Pacific which are adjacent to or near the coast of the Asiatic continent. This includes Indonesia, where "tali rami", a kind of twine used for fishing nets, excited the imaginations of the Dutch and the English East India Companies and later the traders of the nineteenth century, especially during the periods when the Napoleonic Wars and later the Crimean War

disrupted the supply of hemp cordage fiber from Russia. A small qauntity of ramie fiber has been exported from time to time from the Islands of Indonesia to Europe.

Japan has cultivated ramie plants and used the fiber since prehistoric times. At one time, about 300 years ago, the armies of the Shoguns were clothed in uniforms made from ramie. Primitive hand methods of cultivation and hand processing may still be found in the mountain areas of Japan. Japanese ramie is better known, however, as a commercial product.

Only about 1,000 tons of fiber can be grown in Japan annually because of the pressing need for food crops. The mills of Japan, however, need about 10,000 tons annually and in times past imported most of this from China. Presently imports are coming from many parts of the world.

In a few moments, Mr. Averill, the projectionist, will run a film showing ramie fiber processing on a commercial scale in Japan. The methods used in the Japanese mills are approximately the same as those used in the mills in Germany and other European countries.

This picture was made with the cooperation of the world's largest ramie mills which are located in Japan. The Hard and Bast Fibers Trade Association of Japan assisted in making arrangements, as did also the officials of the Prefectures in Japan where the pictures were made.

The actual photography was done by the U. S. Army Signal Corps. Cpl. J. C. Carey and Pfc. David McLean were the photographers. Any rough spots and shortcomings in the picture are to be attributed to me since responsibility for planning and direction was mine.

The showing of the 30-minute movie that is to follow and which will give many details of the culture and processing of ramie in Japan was cleared especially and exclusively for this meeting by the Office of Public Information of the U. S. Department of Defense.

EDITOR'S NOTE: A group of 18 frames was selected from this film and these, with the additional photo (No. 3) on harvesting, from another source, constitute the series of figures that follows. It is hoped that the rather full legends which Miss Montgomery has provided for these pictures will assist very materially in giving those who did not see the film a good idea of the conditions of cultivation and processing of ramie in the Far East which she has studied for a number of years.

Figure 1. *Preparing the Soil.* The land is first deep-plowed or turned by hand with a mattock similar to the one shown in the picture. It is then well pulverized by a harrow, usually wooden, which may be drawn by horse or pulled by hand. Trenches 7 to 8 inches deep, are then made with the mattock, and fertilizer (compost, barnyard manure and commercial fertilizer) mixed with soil is turned back into the trench from the surface ridges to a depth of about 2 inches.

Figure 2.—*Planting.* Ramie may be propagated in 3 ways: by seed, by rooting cut pieces of the mature stalk and by cut pieces of the root system, which are known as rhizomes and sometimes as "reproductive roots." The last named is the most satisfactory and widely used. In the picture, cut pieces of rhizomes are being placed in the trench. Pieces are about 4 to 5 inches long and care is taken to have each piece with two or three buds. Soil is then turned into the trench, with the mattock, to cover the rhizomes. Plants begin to appear above ground 7 to 10 days after planting. The field is then inspected and any dead pieces of rhizomes replaced.

Figure 3.—*Harvesting.* Stalks are cut by hand with a sickle. Plantings, in the latitude of Kyushu, Japan, require from 1 to 2 years for the root system to spread out and become well-established. Fields are weeded by hand until roots spread out to provide enough stalks to shade the ground. Cultivation of plants and application of fertilizer also is by hand, at regular intervals. The first stalks sent up are cut when they reach a height of 3 to 4 feet, and allowed to remain on the ground. The cutting encourages the root system to spread out. Allowing stalks to remain on the ground also helps to prevent weeds, conserve moisture, and enrich the soil. This preliminary cutting is usually done twice during the first year. The third growth, if conditions have been favorable, can be cut for fiber extraction, though yield per acre will be low. By the second year the root system will be sufficiently established to provide satisfactory yield of fiber at 60 day intervals during the warm growing season. In Kyushu, 3 crops may be harvested per year, resulting in an average of 1,100 pounds of fiber per acre, with higher yields from fields that receive good care, adequate fertilization and have a favorable growing season. Plants in the picture are 2 years old.

Figure 4.—*Transporting Stalks to Decorticator.* The decorticator, a machine for extracting the fiber from the stalk, is portable and is moved to a place near the field where harvesting is done. Stalks are moved to the decorticator on small, two-wheeled carts. Note that stalks have been placed on cart with root ends even.

Figure 5.—*Decortication.* This operation removes the fiber from the stalk. To obtain the highest quality and the greatest quantity of fiber, stalks should be run through the decorticator as soon as possible after harvesting.

Ramie fiber is located in bast bundles that occur in the outer part of the stem which completely surrounds the central woody portion, just under the outer bark and running the full length of the stalk. The bundles are held in place by gummy and waxy substances and by the cellular tissue around them. The object of decortication is to remove these bundles of fiber from the stalk cleanly and efficiently and with their length intact. Machines used for this purpose all operate on the same basic principle, which consists, essentially, of crushing stalk between rollers and then bringing it into contact with blades set in the outer circumference of a rotating wheel which scrape bark and woody portions of stalk from fiber.

The machine in the picture was patented in Japan in 1947 and is run by a 3 h.p. motor. Average production is about 400 to 450 pounds of fiber, dried basis, per 8-hour day; skilled operators produce more. The full length of the stalk is decorticated on a continuous basis, no defoliation, topping or butting of stalk being required before decortication.

Decorticated fiber may be seen in the center of the picture, coming from underneath the machine. It is caught by the worker seated on the ground just to the left and beyond the workman who is feeding the machine and hung over the bamboo pole placed on pegs extending from two upright poles—see lower left corner of picture. The pieces of bark, woody material, and leaves fall to the ground below the machine. A pile of this waste material may be seen in the picture. The waste is carefully saved and used as compost for fertilizing the crop. Use of this material reduces to a minimum the amount of nitrogen fertilizer needed.

When fiber has been hung all the way across the pole, another worker removes the full pole and replaces it from a pile, the ends of which may be seen on the left-hand side of the picture. The filled pole is hung on an upright bamboo frame

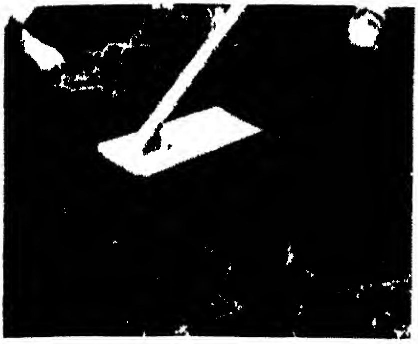

Figure 1

Figure 2

Figure 3

Figure 4

Figure 5

and the fiber is allowed to dry in the open air and sunshine. Drying the ramie ribbons in the sun is considered important as a more lustrous, stronger fiber results than if air-dried in the shade.

Figure 6.—*Brushing.* After the decorticated fiber is thoroughly dry it is brushed to remove any bits of bark and woody material remaining. The brushing machine. also patented in Japan in 1917, is operated by a 2 h.p. motor. Its average production is 250 to 300 pounds of brushed fiber per 8-hour day.

Fiber is brushed by bringing it into contact with very coarse combs set into the outer circumference of a rotating wheel. Note clean, smooth appearance of fiber on the table at the left side of the picture in comparison with fiber on table on the right. Brushed fiber is baled and sent to the mills.

Figure 7.—*Degumming—First Step.* The purpose of the degumming process is to remove the gums and waxes which still remain on the fiber. At this stage, the fiber is in strands or ribbons that are made up of the bast bundles of fiber which run the full length of the original stalks. Each strand is made up of many individual fibers, which may range in length from ½ to 20 inches and usually average 5 to 6 inches. Removing the gums and waxes frees the individual fibers so they may be better sorted, combed, and twisted during the spinning operations. Ramie is the only bast fiber which can be separated into individual fibers before any yarn preparation or spinning operation takes place. The unusual length of the individual fibers makes this possible and practical.

When the bales of fiber reach the mill, they are opened and the fiber inspected. It is then tied in small bundles, using one end of a strand of fiber. These small bundles are tossed onto a scale and when the specified weight is reached, are placed in a wire basket for the first step in the degumming process.

In the picture, the wire basket loaded with ramie fiber is being moved toward the first step in the actual degumming process. This consists of placing the basket and its contained fiber in a clean, empty vat and covering it with clear, cold water for about 24 hours or until the fiber is thoroughly re-wetted. This is important to allow thorough penetration of the degumming solution, into which basket of fiber is next immersed.

Figure 8.—*Degumming—Second Step.* The degumming solution, into which the basket of fiber is immersed, consists of a water solution of caustic soda, the amount of caustic soda depending upon the quality of fiber and amount of gums and waxes it contains. The solution is kept at boiling point and the fiber remains in it about 4 hours, again depending upon quality of fiber and amount of gums and waxes on it. Agitation, during the boiling, is by hand with a wooden pole, as shown in the picture. Care must be used in stirring fiber to avoid tangling.

Properly done, boiling in the degumming solution will soften and largely remove gums and waxes and leave fiber clean with strength, luster, and other desirable qualities intact.

After boiling, fiber may or may not be rinsed in a solution containing a chemical to neutralize caustic soda, depending upon procedure at mill. Sometimes mechanical agitation and plain water are used for neutralizing.

Figure 9.—*Washing.* After boiling and neutralizing, fiber, while still wet, is washed thoroughly in clean water to remove any gum and wax which has been loosened but not removed during the preceding operations.

Figure 10.—*Drying Degummed Fiber.* After washing, the fiber is soaked in an emulsion of oil and water and hung over bamboo poles. These are suspended from open-air racks until fiber is dried.

Figure 11.—*Sorting Fiber by Lengths, First Step.* After drying, degummed fiber is run through a softening machine, sprayed lightly with an emulsion of oil and water and aged in a humidifying room for about a week. Fiber is then taken o fiber preparation room to be sorted by lengths.

The first machine, into which fiber is being fed in the picture, is called a Large Filling Engine. Fiber is given first combing on this machine, being caught onto a large drum at the back of the machine by means of teeth placed in single rows at intervals across the surface of the drum. Fiber is then cut into 12 inch lengths and combed lightly again while still caught on these teeth. It is removed from the drum by placing small willow sticks across the center of the 12 inch lengths and doubling the fiber over the sticks. At this stage fiber is termed "fringe."


Figure 6

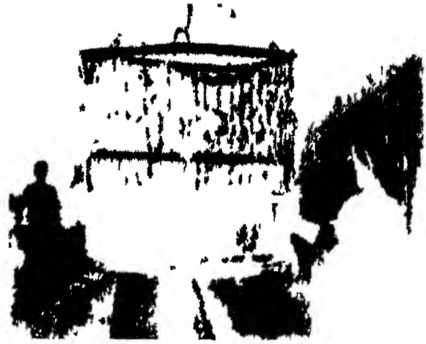
Figure 7


Figure 8


Figure 9


Figure 10


Figure 11

Figure 12.—*Sorting Fiber by Lengths. Second Step.* The fringe, i.e., sticks with fiber over them, is taken to a large machine called a dressing frame. Sticks with fiber over them are locked into place at the top of a large, slowly revolving drum by an operator who stands on a high platform in back of the machine. Ends of fringes, just after they have been locked into place, may be seen on the upper part of the drum in the picture. As the drum revolves the ends of the fringes are brought into contact with rolls covered with wire teeth, which are located under the drum and which comb the fiber, removing the shorter lengths.

When the drum has made a complete revolution, the operator reverses the fringe, locking it into place again by placing one end between two wooden slats. The willow sticks are allowed to hang loosely against the length of the fiber. They are removed by a second operator when the reversed fringe reaches the front of the machine. As the drum revolves, the length of the fringe is brought against the combing rolls. In the picture, reversed fringe, hanging to its full length, may be seen on the lower part of the drum as it is moving down toward the combing roll. The operator standing to the left of the machine has just removed the willow sticks from the reversed fringe.

When the second revolution of the drum is completed, fringe is removed by the operator standing on the platform in back of the machine. Slats holding ends of fringe are loosened, a piece of light weight canvas laid over it and the fiber rolled into the canvas. Operation of the machine is continuous.

Shorter fibers are removed from the combing rolls in the form of laps and again sent through other filling engines and dressing machines to remove the shortest fibers. This results in sorting fiber into 3 lengths: long, from the first dressing frame: medium, from the second dressing frame; and short, which is fiber from filling engines and second dressing frame. Sorting fiber by lengths permits spinning of more even and stronger yarns.

Figure 13.—*Combed Fiber.* Rolls of fiber from the dressing frame are taken to the picking room, where fiber is spread over desks with lighted. ground glass tops and any remaining imperfections picked out by hand with tweezers. Girls who perform this operation work very rapidly. As inspection of each fringe is completed, fibers are pushed together into the small bundles shown in the foreground of the picture. Each of these bundles is again given a rapid inspection and placed on the wooden rack seen in the picture. At this stage the fiber is known as "filasse." The bundles of filasse are placed in large shallow boxes and taken to the yarn preparation room. Note that at this stage individual fibers have been completely separated from each other.

Figure 14.—*Forming the Lap.*—When they reach the yarn preparation room, the bundles of filasse are first weighed. If they are not of a specified weight, they are sent back to the picking room to be remade. Ten bundles of filasse are then taken to a machine called a spreader, which forms a lap as the first step in yarn preparation. At this machine, bundles of filasse are again weighed. They are then placed one by one, with ends overlapping, on a narrow endless belt, which may be seen in the right foreground of the picture. This belt carries the fiber between rollers and under a series of gill pins, i.e., a kind of comb, which makes the fibers more nearly parallel to each other. The fibers are then fed in the form of a ribbon onto a large wooden drum.

When the last or tenth bundle is placed on the belt the operator laps the ends of the first of another group of bundles over the ends of the last bundle and pinches these two ends together, causing the lap to become narrow at that point. When this narrow place appears on the drum, it is a signal to the operator that an entire lot of bundles has been made into a lap and is ready to be removed from the drum. The operator in the picture is removing a lap from the drum, an operation requiring considerable skill as the work must be done in such a manner that the arrangement of the fibers is not disturbed. The lap is carefully folded as it is removed and taken to a setting frame.

Figure 15.—*Forming the Sliver.* The lap is fed into the setting frame through a series of rolls and under gill pins which reduce its size and continue the process of arranging the fibers more nearly parallel to each other. The lap is also twisted slightly, forming what is known as a "sliver". Picture shows sliver coming from machine. Note that the machine puts a crimp in it. This helps hold the fibers together. Sliver is coiled in tall cans for transferring from one machine to another.

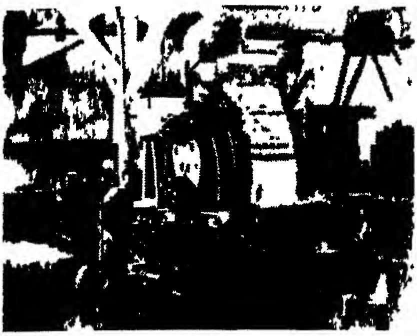

Figure 12

Figure 13

Figure 14

Figure 15

Figure 16.—*Drawing or Doubling.* Several slivers are fed into a drawing frame, an operation which is sometimes termed doubling. The slivers pass between rolls and under gill pins which first combine them into one sliver and then decrease the size of this sliver by drawing it out to a greater length. A small amount of additional twist is then put into it. This operation is repeated as often as necessary for the size of yarn that is to be spun in relation to the quality and size of fibers being used.

Figure 17.—*Making the Roving.* After the sliver, as a result of drawing, is of proper size and density, it is fed into a roving frame which again reduces it in size and puts additional twist in it. The result is called roving. As the roving is formed, it is automatically wound onto a wooden spool. When all of the spools on a rack are filled, they are removed from the rack and empty spools substituted.

Depending on the fineness of the yarn to be spun, roving may be fed through a second roving frame to reduce it still further in size and to increase the twist.

The spools of roving, when properly formed, are then taken to the spinning frame where the roving is again reduced in size and twist increased. The result is termed yarn. As it is spun, yarn is automatically wound onto small wooden bobbins.

Figure 18.—*Weaving.* After spinning, warp yarns, that is yarns which run lengthwise the fabric, must be starched to give them additional body for the weaving process. This starch is later removed from the finished fabric. After starching, warp yarns are wound onto a large cylinder which is locked into place at the back of the loom after the ends of the warp yarns have been threaded through the eyes of a series of very narrow pieces of steel, called "heddles", which are fastened into a frame called a "harness". Two or more harnesses are used in weaving. The mechanism of the loom lifts the harness in turn, thus holding the warp yarns apart and allowing the shuttle to carry the filling, that is, cross-wise yarn, back and forth to form the fabric.

The loom in the picture is making a plain weave fabric, using two harnesses. The fabric being made weighs 4 ounces per square yard. Mr. Goro Kawasumi, president of Toyo Sen-i Company, the firm owning the mills in which these pictures were taken, is observing the loom in operation.

Figure 19.—*Products Made from Ramie.* A large number of yarns, twines, and cordage fabrics, all made from ramie, are on the table. A rug made entirely from ramie is on the floor. A coil of fire hose made from ramie yarns is being carried onto the scene.

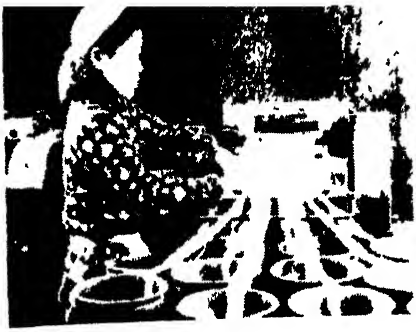

Figure 16

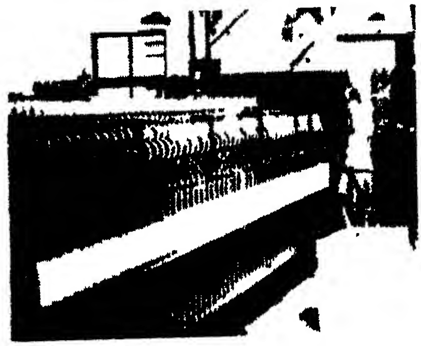

Figure 17

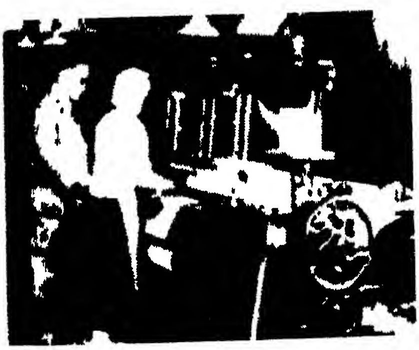

Figure 18

Figure 19

JUTE—FROM FIELD TO FIBER IN PAKISTAN

ELTON G. NELSON

Nearly all the jute and burlap used in the United States comes from Pakistan and India—halfway around the world. It was this distance and the threat of World War that stimulated the effort to produce a substitute in the Western Hemisphere for this versatile commodity. That substitute was kenaf. Kenaf production and processing is being mechanized but since hand-produced jute still sets the pace, it is important to know how it is grown and marketed.

Most of the jute in Pakistan and India is grown by small farmers and it is their principal cash crop. They have only a few acres and their farm implements are simple. They grow jute much as their forefathers did. The land is plowed with a crude wooden plow drawn by oxen. The seed is planted. the crop is thinned and weeds are pulled—all by hand. At harvest time the crop is cut with hand sickles. The stems are cut near the ground and tied into small bundles. either with strips of jute bark or hand-made twine. These bundles are usually left in the field for a few days. until the leaves fall off. Then they are taken to nearby pools or to slow-moving water along the edges of rivers for retting (a process of fermentation). This process takes from 10 days to 3 weeks, depending on the maturity of the stems and the temperature of the water. Removing the stems at the proper time is one of the most important factors in the production of good-quality fiber. When the jute farmer decides his jute is sufficiently retted, he wades out into the water, removes a bundle, unties it. and beats the base end of it with a small paddle-shaped club to partly loosen the fiber. Then, still standing in the water, he strips off the fiber by hand and washes adhering bark and other foreign material from the fiber by flicking it over the surface of the water. There are modifications of this procedure but the one described here is most common: all jute in Pakistan and India is stripped by hand.

Jute is dried by hanging it over bamboo frames. When it is dry. it is tied into bundles for the market. From the farmer to a middleman. on to another middleman. etc.. jute is eventually accumulated at the baling centers. It comes in by oxcart or by small riverboats. either propelled by hand or by sail.

Jute is usually sorted and baled twice—first into "kutcha" bales for local transport. and second into "pucca" bales, for export. The kutcha assortment (preliminary grading) consists of top, middle. bottom. and cross-bottom and is expressed as one of these grades in connection with the town from which it originates. At this stage the fiber moves in bales weighing 250 to 320 pounds.

From the kutcha baling centers, jute usually moves to the pucca presses by rail. large riverboats and barges. As the jute comes into these large baling centers. it is given a final sorting. Since the fiber from the

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base of the stem is usually barky, 6 to 18 inches is cut off prior to grading. The fiber is then separated into several grades according to color, strength, cleanliness, appearance, etc. For each type of jute (white, tossa and Daisee) there are about 10 grades, known as public marks, but in practice, balers use their own private designation. As a result there are more than a thousand different marks or brands. The sorted fiber for export is pressed into high-density bales, about 18 by 18 by 48 inches, weighing 400 pounds each. Nearly all jute that is shipped to foreign countries goes in pucca bales, but that going to the jute mills in Calcutta is often transported in the low-compression bales, even after the pucca assortment.

The United States uses about 70,000 tons of raw jute annually: most of it is tossa, *Corchorus olitorius*. We buy the best quality fiber available.

Burlap has never been manufactured in this country, but we import about 250,000 tons annually from India. The burlap used in the United States is known in the trade as hessians and is made from a very high quality white jute, *C. capsularis*. Lower qualities go into a much heavier material called sacking—which makes up about 45 percent of the output of India's jute mills.

The methods of producing jute in Pakistan and India may seem backward. Nevertheless these methods provide us with high quality fiber. Any substitute produced mechanically will be judged by the standards established by hand-stripped jute.

The series of pictures which follow will give a good idea of some of the more important steps in jute culture and processing that have been briefly described above.

Figure 1.—"Laddering" preparatory to planting. This corresponds to harrowing as we normally do it. Plants in the background show jute ready for harvest. The land preparation is not for jute planting.

Figure 2.—Harvesting jute with hand sickles. (Photo courtesy Ludlow Mfg. & Sales Co., Boston.)

Figure 3.—Placing jute in water preparatory to retting. Usually the leaves are allowed to dry and fall off before the stems are removed from the land upon which the crop was grown.

Figure 4.—First step in stripping jute following retting and beating with small paddle Note paddle lying on stems at right.

Figure 5.—Preparing to pull fiber from upper part of stems.

Figure 6.—A more general view of the stripping operations shown in Figs. 4 and 5.

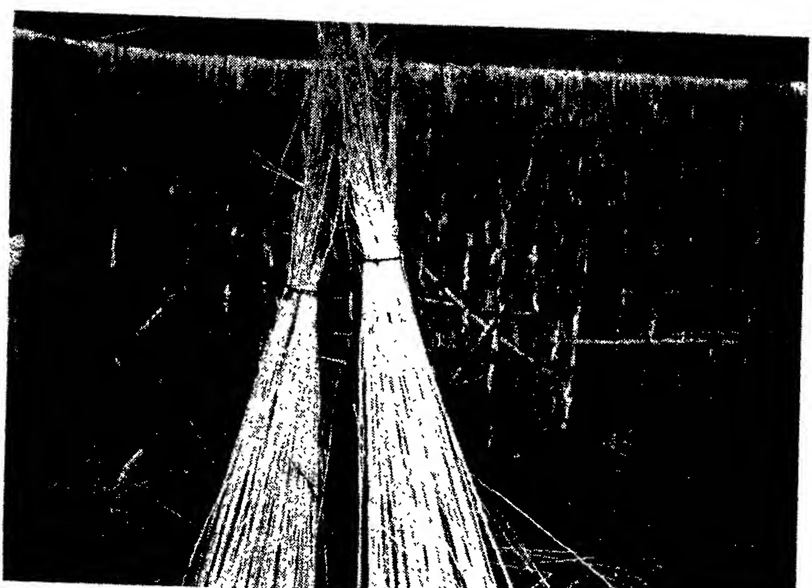

Figure 7.—Drying jute on bamboo poles. Note stripped stems in the foreground and the wall of the building in the back that was made from such stems. Near Sarisabari, Pakistan.

Figure 8.—Carrying loose jute from riverboat to sorting shed. Dacca, Pakistan.

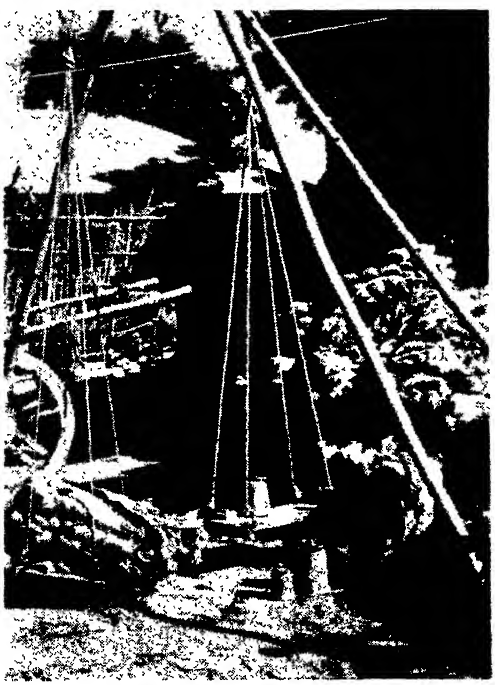

Figure 9.—Weighing loose jute.

Figure 10.—Cutting jute preparatory to sorting. In this operation from 6 to 18 inches is cut from the base end of the fiber. It is to be hoped that the man was posing when the picture was taken.

Figure 11.—Softening the ends of cut jute. Narayanganj, Pakistan.

Figure 12.—Making jute ropes for tying bales, Dacca, Pakistan.

Figure 13.—Left: Kutcha bale weighing about 300 lbs. that is commonly used for domestic shipments. Right: Pucca bale for export weighing about 400 pounds that has been compressed to a density of about 40 pounds per cubic foot. The narrow dimension of the kutcha bale is about the same as that of the pucca which is approximately square. Narayanganj, Pakistan. (F.I. Note: Mr. Nelson in photo.)

Figure 14.—Pucca bale press, known as the Cyclone, is capable of exerting pressures up to 2½ tons per square inch. (Photo courtesy Ludlow Mfg. & Sales Co., Boston.)

Figure 15. — Coolie team carrying kutcha bale of jute, Narayanganj, Pakistan.

SODIUM AS A PLANT NUTRIENT

CHESTER D. LEONARD * and ERNEST C. LUNDBERG *

The role of sodium (Na) in the physiology of higher plants has long been, and still is, a controversial one. This paper includes a fairly comprehensive review of the literature pertaining to sodium in this role, since little information concerning this element has been published to date in Florida. Certain experiments with Na which were carried out by the writers are also reported.

LITERATURE REVIEW

It is well known that Na is essential to animal life, where it is used chiefly in the form of NaCl. Na is probably necessary to marine plant life, or at least to much of it. Osterhout (31) found it essential to several forms of algae. However, it has never been recognized as one of the essential or indispensable nutrients for the higher plants. Harmer and Benne (15) have pointed out that its presence in considerable amounts in plants has often been considered incidental, so Na has not been credited with any definite function in the metabolism of the plant. However, Lehr of Holland (23) has emphasized two points of view in considering the importance of Na to plants: the *botanic-physiological point of view*, which concerns itself with the presence or absence of deficiency symptoms in the plant when Na is withheld, and the *agricultural point of view*, which concerns itself with improving the yield and/or quality of the crop by adding Na to the growing medium.

Gilbert (12) defines an essential or "nutritive chemical element" as "one whose reduction in the diet results in decreased growth, structural abnormality, and possibly death of an organism, depending on the degree of deficiency, and whose total omission makes it impossible for the organism to exist." To date it has not been shown that higher plants cannot exist without Na. Therefore it does not meet the above requirements for an essential or "nutritive chemical element" under the botanic-physiological point of view exponded by Lehr. On the other hand, many of those crops which show no deficiency symptoms when Na is withheld have been found to produce a higher yield in both the greenhouse and under field conditions when Na has been furnished. Na has been shown, therefore, to be of considerable importance from the agricultural point of view. Wallace (41) has classified it as a "beneficial" element for certain plants.

Na is a soft, waxy, silver-white, metallic element of the alkali group. It is univalent, very active chemically, and forms a large number of important soluble salts. It occurs abundantly in the earth's crust, with 3.71% Na_2O in the outer ten miles of the lithosphere, according to the calculations of Clarke (7). On this basis, Na is the fifth most abundant mineral element in the earth's crust, ranking behind Si, Al, Fe, and Ca. It always occurs in combined form in nature, as in halite (common salt),

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Chile saltpeter, borax, glauberite, albite, diorite, and other Na-carrying minerals.

Na has been applied to soils as a fertilizer for many years as sodium nitrate, but its application was long considered merely incidental to the application of nitrogen.

Physiological Response of Plants to Na

Color of Foliage and Plant Vigor

Harmer and Benne (15) found that sugar beets fertilized with NaCl kept a vigorous, healthy green foliage longer than those without NaCl. Mangels fertilized with Na applied as $NaNO_3$ develop what Lehr (24) calls the "Na-type" of top with spreading foliage and light green color with abundant leaves, whereas calcium nitrate develops the "Ca-type" of top with compressed growth habit and dark green color, but with early withering of outer leaves.

Sayre and Vittum (34) found that table beets grown with an adequate supply of Na develop leaves that are brighter green in color and much more palatable as to flavor than those grown without it. Table beets receiving Na also developed large, strong tops which stood erect and were much better adapted to mechanical harvesting.

Tomatoes, corn, and wheat grown in sand and solution cultures develop thicker, fleshier leaves with a higher water content when an abundance of Na is furnished them (18, 6). Tomato plants grown in sand cultures with high-Na nutrient solutions display reduction in cambial activity, maturation of smaller cells, and relatively thicker walls in xylem elements and mechanical cells.

Disease Resistance

On organic soils, Na-responsive crops show less damping off in early growth, and the beet crops develop less black rot later on, when NaCl is applied along with K. Beet crops receiving NaCl show more resistance to attacks of leaf spot (*Cercospora beticola*) and celery shows more resistance to blight (*Septoria petroselini appli*). The greater gloss of leaves of these crops produced by NaCl is possibly due to an increased waxy secretion which may account for the increased disease resistance (15).

Decreased Wilting in Hot, Dry Weather

Harmer and Benne (15) report a decrease in evaporation from the soil following the application of NaCl. They found that on an organic soil, the surface of a salt-treated soil stays more moist with the result that the soil is less subject to blowing by high winds than is an unsalted soil.

Keeping Quality of Crops

Celery receiving NaCl as a fertilizer has been found to be crisper and to stay in better condition when exposed on the market (15).

Effect of Na on Absorption of Other Ions by Plants

Collander (8) found that a given plant species will exhibit a consistent type of selective absorption of several ions, but that there were wide differences in the relative selectivity among various species. All halophytes but one were distinguished by their accumulation of Na.

whereas plants like buckwheat, corn, and sunflower were noted for their pronounced exclusion of Na. Collander stresses the very complex nature of the selective salt absorption of higher plants. Van Itallie (39) found that the Na uptake depends chiefly on the uptake of K.

In general, the intake of a nutrient ion by the plant increases as the concentration of the ion increases in the growing medium. This has been shown by numerous workers.

The absence of Na in the nutrient medium of Na-responsive crops has been found to increase the absorption of K (2, 11, 15, 26). In the absence of K, however, it is evident that Na is unable to take over some of the important functions of this element, and a physiological breakdown results. In some cases the addition of Na to the nutrient medium will increase the intake of K by the plant (11, 6, 37). In a clay soil, Na intake by plants was found to be higher with a high level of calcium carbonate, probably because of Na displacement from the exchange complex by Ca of the carbonate (37).

The effect of Na on absorption of other ions varies with the nature of the accompanying anion. Breazeale (5), found that NaCl in concentrations up to 1000 ppm. in a nutrient solution did not affect the absorption of phosphoric acid by young wheat plants but decreased slightly the absorption of potash. Sodium sulfate in the same concentration depressed the absorption of potash and phosphoric acid to about 70 percent of that of the control. Sodium carbonate, on the other hand, in a concentration of 1000 ppm., reduced the absorption of potash to 20 percent of that of the control and the absorption of phosphoric acid to 30 percent of that of the control. The depressing effect of sodium carbonate was evident in concentrations as low as 100 ppm., and was marked at 300 ppm.

It has been noted in certain crops that the total milliequivalent content or "cation sum" of the four bases K, Na, Ca, and Mg tend to remain fairly constant (15, 40), but marked deviation from a constant value is encountered with some Na-responsive crops when they are provided with an abundance of the element.

Yield Responses of Various Crops to Na

Mangels

Mangels have been found to produce large increases in yield when fertilized with Na (1, 13, 22, 24, 25), even when large amounts of K are also added. This is shown by a pot experiment of Lehr, some results of which are reported in Table 1. Lehr (22) concluded that by the use of Na fertilizer, a notable saving of potash fertilizer may be made on this crop. In his experiments, the yield of roots with sodium nitrate and no K was 20 to 30 percent higher than that produced with either calcium nitrate or ammonium nitrate at any level of K. Harmer (13) obtained similar large increases of mangel yields with NaCl on organic soils in Michigan.

Sugar Beets

Sugar beets show a marked response to Na fertilization, but there is often an accompanying lowering of the apparent purity coefficient $\left(\frac{\text{percent total sugars} \times 100}{\text{percent soluble solids by wt.}}\right)$ of the beet juice (13, 15, 20, 28, 35). In spite of lower purity of the juice, Lill, Byall, and Hurst (28) found that

the *total recoverable sugar* increased with each addition of NaCl from 250 to 1000 lbs per acre. Selman (35) reports that NaCl must be used with phosphate and KCl for highest yields of roots.

TABLE 1—YIELDS OF MANGELS IN GRAMS DRY WEIGHT PER POT WITH THREE NITROGEN FERTILIZERS AND VARYING POTASSIUM (WORK OF LEHR)

	No K	Normal K	Very High K
ROOTS			
$NaNO_3$	91.9	99.0	106.5
$Ca(NO_3)_2$	63.5	50.5	59.8
NH_4NO_3	54.0	65.9	54.0
TOPS			
$NaNO_3$	50.6	59.7	61.8
$Ca(NO_3)_2$	47.7	42.7	48.0
NH_4NO_3	45.5	18.6	52.7

Cotton

The yield of seed cotton has been found to be materially increased by Na fertilization using either sodium nitrate or common salt (9, 10, 20, 29). Mathews (29) found that the average increase due to Na was 40 percent of that due to K. When 32 lbs K_2O was applied per acre additional Na failed to increase yields.

Table Beets

This crop produced a marked yield increase when fertilized with Na (13, 14, 15, 33, 34). Sayre and Vittum (34) also found that the use of 500 lbs of NaCl per acre on table beets, together with a heavier than normal rate of planting would produce a greater percentage of the higher priced small beets without reducing total yield of roots. Some yields of table beets with and without Na are shown in Table 2.

TABLE 2—6 YEAR AVERAGE YIELDS OF TABLE BEETS GROWN ON MUCK SOIL IN MICHIGAN WITH VARYING AMOUNTS OF NA AND K IN THE FERTILIZER (WORK OF HARMER)

Fertilizer Application Each Year 600 Lbs. Acre	Yearly NaCl Lbs. Applied	Yield of Roots Tons/Acre
0-8-24	0	10.4
0-8-24	500	19.5
0-8-24	1000	21.9
0-8-12	500	18.2
0-8-45	0	17.0
0-8-0	500	5.6

Turnips

Substantial increases in yield of turnips have been obtained (13, 14) by adding either 500 or 1000 lbs. of NaCl per acre to organic soil in

the field (Table 3). Large growth increases have also been obtained in sand culture (20).

Celery

Harmer (13, 14) has obtained substantial increases in celery yield by adding either 500 or 1000 lbs. of NaCl per acre to organic soils in the field but such increases were obtained only when K was furnished (Table 3).

TABLE 3.—YIELDS OF CELERY, SWISS CHARD AND TURNIPS GROWN ON MUCK SOIL WITH VARYING AMOUNTS OF Na AND K IN THE FERTILIZER (WORK OF HARMER)

Yearly Fertilizer 600 Lbs./Acre	Yearly NaCl Lbs.	Yields Tons/Acre		
		Celery	Swiss Chard	Turnip
0-8-24	0	19.2	17.7	[illegible]
0-8-24	500	25.5	26.5	15
0-8-24	1000	25.5	31.0	15.5
0-8-12	500	22.5	25.5	11.5
0-8-[illegible]	0	22.[illegible]	25.[illegible]	12.4
[illegible]-0	500	11.9	[illegible]	[illegible]

Swiss Chard

NaCl applied at the rate of either 500 or 1000 lbs. per acre to organic soils in the field has produced large yield increases of Swiss Chard (13, 14, 15) as shown in Table 3. It will be noted that an 0-8-24 fertilizer with no NaCl produced 17.7 tons of Swiss Chard per acre. The same fertilizer plus 1000 lbs. NaCl produced 31.0 tons per acre.

Oats

Holt and Volk (20) obtained marked yield increases of oats in sand cultures by adding Na even after adding 141 lbs. K_2O per acre.

Wheat

Sand and solution culture studies have shown that wheat will respond well to Na fertilization (4, 6, 20). Butkevich and Maruashvili (6) report that the yield of wheat was increased by Na up to Na/K ratios of about 5, then decreased. They found that Na can be substituted for 25 to 75 percent of the K without detriment to plant yield.

Barley

Lehr (24) states that barley responds well to Na very much like the response of oats. Richards (32) reports that Mullison and Mullison obtained considerable increase in dry weight of barley from Na.

Flax

Some yield increases in flax from Na fertilization have been reported by Hartwell and Damon (17).

Radish

Na salts increased growth of radish as with limited K but the benefit ceased when ample K was supplied (1).

Other Crops

Various workers have reported little or no increase in yield from Na fertilization of onions, cabbage, parsnips, carrots, potatoes, corn, vetch, tomatoes, rice, giant summer squash, soybeans, rutabagas, cucumbers, and chicory. Differing experimental conditions may, however, produce different results. Leonard and Bear (26) found in a field experiment that 265 lbs. Na_2O per acre, applied to the soil in the form of common salt both with and without 100 lbs. K_2O, increased yields of tomatoes to a point closely approaching the level of statistical significance.

General Classification of Crops with Respect to Their Na Responses

Harmer and Benne (15), after extensive review of the literature, have classified those crops on which Na has been tried as a fertilizer into *tentative* groups as shown in Table 4.

TABLE 4.—Tentative Classification of Various Crops with Respect to Their Response to Na Fertilization (by Harmer and Benne).

A. Crops benefited by Na with deficiency of K.

- Group 1. ***None to very slight benefit.*** Buckwheat, corn, lettuce, onion, parsley, parsnip, peppermint, potato, rye, soybean, spinach, strawberry, squash, sunflower, and white bean.
- Group 2. ***Slight to medium benefit.*** Asparagus, barley, broccoli, Brussels sprout, flax, caraway, carrot, chicory, cotton, millet, oats, peas, rutabaga, tomato, vetch, and wheat.

B. Crops benefited by Na with sufficiency of K.

- Group 3. ***Slight to medium benefit.*** Cabbage, celeriac, horseradish, kale, kohlrabi, mustard, radish, rape.
- Group 4. ***Large benefit.*** Celery, mangel, sugar beet, Swiss chard, table beet, turnip.

Some Theories Advanced to Explain the Beneficial Effects of Na on Plants

Many different theories or explanations for the benefits to plants due to sodium fertilization have been advanced. Some of these are listed below.

Na can participate in maintenance of ionic balance in the cell sap. Arnon (2) suggests this theory. Lehr (23) also emphasizes the importance of ionic equilibrium in the plant.

Na serves as a replacement for K in the plant, or a substitute for it. Various workers support this view (10, 15, 20, 25, 30). Lehr (25) found that good production of mangels is impossible without Na. Holt and Volk (20) conclude from their work that Na functioned as an essential plant nutrient for some crops, notably oats, wheat, and sugar beets.

Na may have a function independent of K in the plant. Lehr (25) takes this view with respect to mangels. He believes that Na does not serve as a replacement for K with this crop, but is essential for its proper growth.

Na serves to bring about equilibrium of cations in the plant. Lehr (25) states that in the equilibrium of cations, the decisive factor is the exact proportion rather than absolute quantity. He found that both K and Na exerted a strong influence on the activity of Ca. Garman (10) feels that Na may function actively in over-all ionic balance and buffer-capacity relationships within the protoplasm. Related views are expressed by Van Itallie (38, 39) and by Bower and Pierre (3).

Na decreases evaporation from the soil surface. This effect was noted by Harmer and Benne (15) from NaCl applications.

Na may free K or other plant nutrients in the soil by exchange and thus increase the amount of available nutrients. Lehr (23) discounts this theory. It is evident that if K can be exchanged by Na in the soil, it is already available to the plant. On the other hand, if the K is fixed in the crystal lattice of minerals, it cannot be released by Na, since Na cannot occupy the place of K in this position.

Na increases the osmotic concentration of the cell sap. Garman (10) has suggested this theory. Other workers (14, 16, 18) state that this effect cannot account for the benefits of Na.

Na antagonizes the toxic effect of other elements or salts in solution. Osterhout (31) found this action important in algae. Richards (32) expresses his view of the most likely relationship of Na to K as follows:

"Sodium cannot perform the primary essential function of K. When the K level is too low to exert this function adequately, toxic accumulations of other elements may occur, producing characteristic symptoms and reducing growth still further, or even leading to death of the plant. Na may hinder or entirely suppress such accumulations, thus improving the general condition; it may also increase phosphorus uptake with either favorable or detrimental results. In some plants, such as barley, however, Na may itself accumulate to toxic levels, resulting in secondary injury of a modified type; but in others (beet, mangel) higher internal concentrations are tolerated and considerable improvement results. In these plants Na may exert a beneficial effect even when the K supply is sufficiently high not to limit growth directly; but in barley at high K levels large increases in yield due to Na are not found, although the plant type is again modified in its presence. The toxic effects postulated may indeed be due to unbalanced values of the internal cation ratios, but probably are due largely to direct accumulations."

Na increases availability of phosphorus. Only indirect evidence has been advanced to support this view.

EXPERIMENTAL[1]

Greenhouse Experiment with Red Table Beets

A greenhouse experiment was conducted to determine the value of Na to red table beets. The test was made in 1½-gallon glazed earthenware pots filled with well-washed, quartz sand. Plants were grown from seed and thinned to five per pot. Nine nutrient solutions were used, with three levels of K and three of Na at each K level. Except for variations in K, each solution contained a balanced supply of all known essential

[1] Part of the work reported in this section was carried out in New Jersey and was published in New Jersey Agricultural Expt. Sta. Bul. 752, October 1950.

TABLE 5.—Dry Weight of Table Beets Grown in Sand Culture with Varying Levels of Na and K.

Treatment -- ppm.		Yield in Grams	
Na	K	Tops	Roots
0	195	24.94	38.90
23	195	25.15	37.95
115	195	24.55	32.41
0	20	13.20	10.08
23	20	17.17	19.90
115	20	28.13	31.05
0	4	3.56	0.35
23	4	13.83	6.13
115	4	25.30	3.31

plant nutrients. About two quarts of solution was applied to each pot daily by the continuous-drip method. After 2½ months of growth, the plants were harvested. Yields are shown in Table. 5. The best growth was obtained with the high-K level (195 ppm.). Addition of Na at that level produced no increase in yield. The medium-K level (20 ppm.) was not sufficient for best growth, but addition of Na at this K level resulted in marked increases in yield of both roots and tops. Addition of a medium amount of Na to the medium-K culture nearly doubled the yield of roots. and application of more Na gave an even larger increase in yield.

TABLE 6.—Na and K Content of Table Beets Grown in Sand Culture.

Treatment - - ppm.		m.e per 100 gms.			
		Tops		Roots	
Na	K	Na	K	Na	K
0	195	0	291	1	103
23	195	74	215	7	94
115	195	143	173	20	90
0	20	10	68	2	69
23	20	120	32	37	61
115	20	321	18	84	46
0	4	3	42	7	78
23	4	136	19	57	25
115	4	302	19	100	13

" Milliequivalents in 100 grams of oven-dry tissue. These are expressed as milliequivalents because K and Na do not replace each other gram for gram but in proportion to their combining weights. Thus 39 parts K are equivalent to 23 parts Na. To convert milliequivalents K and Na to percentages, multiply by 0.0391 and 0.023, respectively.

The beets in the low-K and no-Na culture were very small. Addition of Na produced marked increases in yield of both tops and roots at this level of K. but growth was still not satisfactory. Obviously. more K

than was supplied in this treatment was needed for normal growth. This indicates that Na performs only part of the functions of K in the nutrition of beets.

The Na content of both tops and roots increased consistently with each increase in Na at all three levels of K in the nutrient solution, as shown in Table 6. At any given level of Na, its content in the beets increased as the K content of the nutrient solution was reduced. Likewise, the K content of the beets decreased with increase of Na in the nutrient solution. This indicates a replacement of K by Na.

Greenhouse Experiment with Celery

In another greenhouse experiment, celery was grown in sand culture with three levels of K (195, 39, and 8 ppm.). In the pots receiving the two lower levels of K, the difference between that level and 195 ppm. K was replaced by an equivalent amount of Na. The three treatments were as follows: Zero Na and 195 ppm. K; 92 ppm. Na and 39 ppm. K; and 110 ppm. Na and 8 ppm. K. The celery yield increased as the K was reduced from 195 to 39 ppm. and replaced by an equivalent amount of Na. These increased yields were maintained when the K was further reduced to 8 ppm. and replaced by an equivalent amount of Na. Similarly, the Na content of the celery rose rapidly and the K content decreased. Results are shown in Table 7.

TABLE 7.—Dry Weight of Tops and Na and K Content of Celery Leaves Grown in Sand Culture at Varying Na and K Levels.

Treatment		Yield of Tops	Composition	
Na ppm.	K ppm.	gms.	Na m.e.	K m.e.*
0	195	59.2	0	135
92	39	67.2	87	42
110	8	69.1	143	17

*Milliequivalents per 100 grams dry tissue.

Outdoor Pot Experiment with Spinach

An outdoor pot experiment with 18 different treatments of Na and K, each in triplicate, was carried out with spinach, using Sassafras loam soil from a location which had not been farmed for many years. The top 7 inches was topsoil, and the rest subsoil. The topsoil was brought to pH 6.5 by applying a mixture of calcium carbonate and magnesium carbonate at the rate of 6000 lbs. per acre. Each pot received an application of ammonium nitrate equivalent to 100 lbs. N per acre, and monocalcium phosphate equivalent to 100 lbs. P_2O_5 per acre. Boric acid equivalent to 20 lbs. of borax per acre was also applied.

K was applied as KCl at six different rates—0, 25, 50, 100, 150, and 200 lbs. K_2O per acre. At each of these K levels, Na was applied as NaCl at three different levels—equivalent to 0, 100, and 200 lbs. K_2O per acre. The spinach was thinned to five plants per pot.

Yields

At the 0, 25, and 50-lb. levels of K_2O, significant to highly significant yield increases were obtained from both the 100- and the 200-lb. levels of Na. At the 100-lb. level of K_2O, only the 200-lb level of Na produced a significant yield increase. At the 150- and 200-lb K_2O levels Na failed to produce a significant increase in yield.

Comparison of the mean yields of each group of 18 pots receiving the same level of Na (disregarding the different K treatments) shows:

(a) The 100-lb. Na level gave a highly significant increase (1% point) over zero Na.

(b) The 200-lb. Na level gave a highly significant increase over zero Na, and a significant increase (5% point) over 100 lbs. Na.

The above results indicate that Na is of considerable value as a fertilizer for spinach at low to moderate levels of K fertilization.

Outdoor Cylinder Experiment with Spinach

An experiment with spinach, using different sources of nitrogen, was carried out to determine whether the Na in nitrate of soda had any value to this crop. Five treatments were used, in triplicate, including Chilean nitrate of soda, chemically pure sodium nitrate, calcium nitrate, and ammonium nitrate, plus a check with no nitrogen. Each of the four fertilizers was applied at the rate of 100 lbs. N per acre. The cylinders were 36 inches deep and 22 inches in diameter. About 20 inches of subsoil was first placed in each cylinder, and this was covered by 10 inches of topsoil of Sassafras loam. The soil was taken from an area that had not been cropped for many years. It was in good physical condition but was low in available plant nutrients. The cation exchange capacity was 8.0 m.e. per 100 grams of soil, and the exchange level of the various bases in it was as follows: Ca, 0.29 m.e.; Mg, 0.22 m.e.; K, 0.44 m.e. per 100 grams. The soil had an original pH of 4.5. This was raised to pH 6.5 by applying the equivalent of 6000 lbs. of dolomitic limestone per acre in the form of a mixture of chemically pure calcium carbonate and magnesium carbonate. The lime was mixed with the upper 6⅔ inches of soil in each cylinder. Each cylinder also received a basic treatment of 100 lbs. of P_2O_5 per acre applied as mono-calcium phosphate, and also the equivalent of 20 lbs. of borax per acre, applied as boric acid. No K was added to any of the cylinders.

Early Growth of Crops

Within a week after the spinach plants emerged, it was very evident that both of the sodium nitrate fertilizers were far superior to calcium nitrate and ammonium nitrate in promoting growth of this crop at early stages. The soil used in the test was low in available K, and the Na added in the sodium nitrate evidently performed some of the functions of K in these crops.

There was little difference between the growth produced by commercial sodium nitrate and that with C. P. sodium nitrate, although a distinctly heavier stand of spinach was obtained with the commercial source. Both of these sodium-carrying fertilizers gave spinach a distinct boost in growth which started immediately after emergence from the ground. Not only did they produce a better stand on emergence, but they also

produced stronger plants which had a much higher percentage of survival. Many of the plants which came up in the check cylinders and in those receiving either calcium nitrate or ammonium nitrate died within two weeks.

Yields

The yields of the spinach crop are shown in Table 8. It is evident from these data that sodium nitrate was far superior to either calcium or ammonium nitrate under the conditions of this experiment. Since the amount of N applied was the same with each fertilizer the large increases in yield obtained with the two sodium nitrate fertilizers must be attributed to the effect of the Na. This Na has evidently served to supplement the K needs of the plants where insufficient K was available to them from the soil.

TABLE 8—YIELD OF SPINACH GROWN IN SASSAFRAS LOAM SOIL IN OUTDOOR CYLINDERS WITH DIFFERENT NITROGEN FERTILIZERS.

Treatment	Yield – Gm	% of Check
$NaNO_3$—Chilean	23.5	5211
$NaNO_3$—C. P.	21.9	4860
NH_4NO_3—C. P.	1.8	402
$Ca(NO_3)_2$—C. P	1.0	226
Check (No N)	0.4	100

Dry wt., mean of 3 replications
L.S.D.. 3.97 gm. at 5% point;
5.87 gm. at 1% point

Analysis of variance showed that the yields obtained with the two sodium nitrate fertilizers were highly significant (1% point) over all other treatments. The difference between the yields from commercial and C. P. sodium nitrates was not significant.

Plant Composition

The composition of the spinach plants (tops) is shown in Table 9.

TABLE 9—COMPOSITION OF TOPS OF SPINACH CROP GROWN IN SASSAFRAS LOAM SOIL IN OUTDOOR CYLINDERS WITH DIFFERENT NITROGEN FERTILIZERS

Treatment	Na m.e	K m.e	Ca m.e	P Percent
Sodium nitrate (Chil.)	112	23	45	0.50
Sodium nitrate (C. P.)	112	22	42	0.56
Ammonium nitrate	1	27	64	0.45
Calcium nitrate	2	19	70	0.40
Check (no N)	0	21	66	0.33

m.e. per 100 gms. oven-dry tissue

It is evident from the analysis of the spinach plants that the Sassafras loam soil used in this experiment contains very little available Na. since

the Na content of the plants was very low except where sodium nitrate was used. The addition of sodium nitrate greatly increased the content of Na in both tops and roots. There was little fluctuation in K content of the tops, but the plants receiving sodium nitrate had considerably less K in the roots than those receiving the other treatments. The calcium content of the tops was considerably reduced in the plants receiving sodium nitrate. The phosphorus content was greater in the tops of those plants receiving sodium nitrate.

Outdoor Cylinder Experiment with Celery

An outdoor cylinder experiment with celery somewhat similar to that reported above for spinach was also carried out. In this experiment, only one sodium nitrate fertilizer, the Chilean nitrate of soda, was used, and the C. P. sodium nitrate was replaced with potassium nitrate. Each of the four N fertilizers was applied at the rate of 100 lbs. N per acre, and a second application was made three months later because of a delay in obtaining celery plants. It was believed that much of the Na and N from the first application had been lost by leaching.

Before the first application of nitrogen fertilizer, each cylinder received a treatment of 50 lbs. K_2O per acre as KCl, 100 lbs. P_2O_5 as mono-calcium phosphate, and the equivalent of 20 lbs. borax per acre as boric acid.

Yields

The yields of celery tops are shown in Table 10.

TABLE 10.—Yield of Celery Tops Grown in Sassafras Loam Soil in Outdoor Cylinders with Different Nitrogen Fertilizers

Treatment 100 Lbs. N	Green Weight gm.	Dry Weight gm.
Check No N	521	73.0
$NaNO_3$—Chilean	1415	161.0
KNO_3	1472	169.3
$Ca(NO_3)_2 \cdot 4H_2O$	105	57.3
NH_4NO_3	335	46.6

It will be noted that the differences in yield between sodium nitrate and calcium and ammonium nitrates are not so large as they were with spinach. This is not because celery responds less to sodium as a fertilizer, but rather because of the 50 lbs. of K_2O added to all cylinders. No K was added to the spinach. These data show that sodium nitrate was as effective as potassium nitrate, and far more effective than calcium nitrate or ammonium nitrate, in increasing celery growth. It is evident that Na has quite successfully supplemented K in the celery plant. This is in agreement with results obtained with celery in sand culture work.

Composition

The composition of celery tops is given in Table 11.

These data show that the plants receiving commercial sodium nitrate contained much less K than those receiving potassium nitrate, and also

TABLE 11 —COMPOSITION OF TOPS OF CELERY PLANTS GROWN IN SASSAFRAS LOAM SOIL IN OUTDOOR CYLINDERS WITH DIFFERENT NITROGEN FERTILIZERS.

Treatment	Na m e	K m e	
Check—No N	11	21	127
Sodium nitrate (Chilean)	173	18	82
Potassium nitrate	46	90	85
Calcium nitrate	16	28	155
Ammonium nitrate	20	33	135

m e. per 100 grams oven dry tissue.

less than the plants receiving the other treatments. Because of the much higher yield of the sodium nitrate plants, however, they took up more total K than the calcium nitrate, ammonium nitrate, or check plants.

Some comparisons of total intake of K by the celery plants receiving different treatments are recorded in Table 12.

TABLE 12—ABSORPTION OF K BY CELERY PLANTS GROWN IN SASSAFRAS LOAM SOIL WITH DIFFERENT NITROGEN FERTILIZERS

Treatment	K/gm. m e	Yield Dry Wt. gms	Total K (2)x(3)
Check	.239	73.0	17.4
$NaNO_3$	.179	161.0	28.8
KNO_3	.900	169.3	152.4
$Ca(NO_3)_2$	.281	57.3	16.1
NH_4NO_3	.332	46.6	15.5

These data show that the celery plants receiving potassium nitrate took up more than five times as much total K in the tops as did those receiving sodium nitrate. Specifically, 152.4 - 28.8, or 123.6 m.e. more K was absorbed by the potassium nitrate plants than by the sodium nitrate plants. To balance this large difference in K uptake, the sodium nitrate plants absorbed a total of 278 m.e. Na. The potassium nitrate plants, on the other hand, absorbed a total of only 78.0 m.e. Na. The difference between these two amounts is 200 m.e. of Na, which for all practical purposes (as far as yield is concerned) completely performed the functions of the extra 123.6 m.e. of K taken up by the potassium nitrate plants. Since K outweighs Na 39.1 to 23, 123.6 m.e. of K weighs 4.8 grams, whereas 200 m.e. of Na weighs only 4.6 grams. Thus the extra K absorbed by the KNO_3 plants was satisfactorily replaced by a slightly smaller weight of extra Na absorbed by the plants receiving $NaNO_3$.

STUDIES WITH RADIOACTIVE NA (Na^{22})

Several studies were made with radioactive Na (Na^{22}). This is an isotope of ordinary Na and is produced in the cyclotron from magnesium. It is unstable and displays radioactivity as it disintegrates, with emission of beta and gamma radiations, to form neon, an inert gas. It has a half-life of three years.

When Na^{22} is fed to plants in solution it is absorbed by them like ordinary Na. Its presence in very small concentrations in any plant part can be detected by using a Geiger counter. Since the radiations emitted by Na^{22} will darken a photographic film, a radioautograph showing distribution of the Na^{22} in a leaf or other plant part containing the isotope can be made by exposing the film to the plant part in the dark.

In one test, a tomato plant was grown to maturity in sand culture. using a complete nutrient solution without Na. One microcurie[2] of Na^{22} was supplied to the plant 7 days before harvest. Table 13 shows the concentration of the isotope in the various plant parts.

TABLE 13.—ACCUMULATION OF NA^{22} IN MATURE TOMATO PLANT AFTER TREATMENT IN SAND CULTURE WITH 1 MICROCURIE OF THE ISOTOPE.

Plant Part	CPM *
Petioles. large new leaves	15,600
Growing point	10,000
Large new leaves	5,800
Petioles, old leaves	2,800
Old, mature stems	3,100
Old leaves	800
Green fruit, ¾ inch diameter	7,700
Green fruit, 2½ inches diameter	3,300
Large newly ripened fruit	3,100
Dead-ripe fruit	2,000

* Counts per minute per gram dry tissue, as measured in plant ash by Geiger counter.

It is obvious from these data that the younger parts of the plant contained the larger amounts of Na^{22}. With increasing maturity, the leaves, stems, and fruit contained less Na^{22}. The conducting tissues contained the highest concentration of the isotope, as shown in the petioles of large new leaves.

TABLE 14.—RATES OF ABSORPTION OF NA^{22} BY TOMATO PLANTS GROWN IN POT CULTURE AND TREATED WITH 2.5 MICROCURIES OF THE ISOTOPE.

Hours	195 K Leaf	No Na Petiole	8 K Leaf	110 Na Petiole
¼	0	0	0	0
½	0	34	0	72
1	0	89	56	448
3	0	176	630	879
18	96	363	2676	....
42	273	......	4473	6465
66	591	663	7506	11124
90	765	747	3354	4221
94	339	282	3933	18357

[2] One microcurie is the amount of the radioisotope required to emit 2.200.000 radiations per minute, or 37,000 radiations per second.

In another experiment with radioactive Na, tomato plants were grown in sand cultures at three levels of K and Na until they were 4 feet high and were bearing small green fruit. Radioactive Na^{22} was applied at the rate of 2.5 microcuries to the surface of the sand in the pots and watered in with the same type of nutrient solution that had been supplied previously to the plants. The first mature compound leaf below the growing tip, normally about 6 inches away, was collected and separated into leaflets and petioles. Movement of Na^{22} into the leaves and petioles sampled is shown in Table 14 for the highest and lowest levels of K.

The figures given in the table represent counts per minute per gram of dry tissue, as measured in the plant ash with a Geiger counter.

No movement of Na^{22} into the petioles of the first mature leaf was noted until one-half hour after it was applied to the sand. Translocation of Na^{22} from the petioles into the blades of the leaflets in detectable amounts did not accur with the high-K and no-Na treatment until sometime between the 3- and 18-hour sampling periods. With the low-K and high-Na treatment, however, the presence of Na^{22} in the leaflets was noted after 1 hour. The intake of Na^{22} was considerably greater in the low-K treatment.

In work reported elsewhere, Leonard and Toth (27) found appreciable concentrations of Na^{22} in celery leaves and stems only 15 minutes after application of the isotope to the nutrient medium. Na^{22} was found to be concentrated in the plant sap of tomatoes, radishes, oats, and lettuce where from 57 to 91 percent of the absorbed Na^{22} was found.

Stewart and Bear (36) made radioautographs of Ladino clover plants fed Na^{22}. One plant received abundant K and contained about 6% K in the tissue; in this plant the Na^{22} was concentrated in the stems and old leaves, with considerably less in the young leaves and growing point. The other plant received inadequate K, and contained only about 1% K in the tissue; in this plant, the Na^{22} was concentrated in the growing point and young leaves, with considerably less in the older leaves.

Uptake of Na by Citrus

Experimental work with Na uptake of citrus trees and its effects on their growth is now in progress. A few preliminary results of this work are presented herewith.

Greenhouse Experiment

A preliminary 3 x 3 factorial experiment, without replication, was run in the greenhouse to study the uptake of both Na and K when these elements were supplied in varying amounts in the nutrient solution. Rough lemon trees, grown from cuttings, were planted in well-washed quartz sand in clay pots painted inside with bituminous paint. The sand in the pots receiving no K was washed with strong HCl and then washed with deionized water until no chlorides remained. The plants were fed with a nutrient solution which was complete except that it contained no K.

There was no noticeable difference due to treatment in growth of the plants during the 6 months this experiment was in progress, except for a few leaf symptoms. However, the chemical analyses of the leaves and roots, as presented in Table 15, show considerable differences in uptake of Na and K under the different treatments.

TABLE 15.—Na and K Content of Rough Lemon Cuttings Grown in Sand Cultures at Varying Na and K Levels.[a]

Treatment Levels		Leaves			
Na ppm.	K ppm.	Na Percent	K Percent	Na Percent	K Percent
0	0	0.098	0.24	0.029	0.37
46	0	0.383	0.19	0.312	0.26
230	0	0.746	0.29	0.604	0.36
0	4	0.242	0.60	0.212	0.33
46	4	0.212	0.33	0.483	0.42
230	4	0.483	0.50	0.260	0.69
0	78	0.075	1.15	0.123	1.25
46	78	0.080	1.63	0.053	1.15
230	78	0.475	1.90	0.108	0.96

[a] The nutrient solutions were made up as follows: 0.0045 M $Ca(NO_3)_2$; 0.0040 M $MgSO_4 \cdot 7H_2O$; 0.00075 M $NH_4H_2PO_4$; 0.04 ppm. Zn; 0.50 ppm. Fe; 0.29 ppm. Mn; 0.04 ppm. Cu; and 0.26 ppm. B.

Na and K were added, in the amounts indicated, as the sulfates.

At the zero K level, it will be noted from Table 15 that the Na content of both leaves and roots increased regularly as the concentration of Na in the nutrient solution increased. The K content varied erractically, dropping at the 46 ppm. level of Na in both leaves and roots, with little difference between the zero Na and the 230 ppm. Na levels.

At the 4 ppm. K level, the behavior of Na in the leaves and roots was more irregular than at the zero K level. In the leaves, the Na content was slightly lower at the 46 ppm. Na level than at the zero Na level, but increased considerably at the 230 ppm. Na level. In the roots the Na content was highest at the 46 ppm. Na level, and decreased at the 230 ppm. Na level. The K content of the leaves decreased somewhat irregularly as the Na level rose in the nutrient solution, but the K content of the roots increased with increasing Na level of the nutrient solution.

At the 78 ppm. K level, which is considered an adequate supply of K for citrus, the Na content of the leaves increased only slightly with 46 ppm. Na in the nutrient solution, but increased greatly at the 230 ppm. Na level. At the same time, the Na content of the roots decreased irregularly as the Na level rose in the nutrient solution. The K content of the leaves increased with increasing levels of Na, but decreased in the roots. Thus, at an adequate K level, Na and K behaved almost alike with increasing concentration of Na in the nutrient solution.

At the 230 ppm. Na level, the Na content of the leaves was greatest with zero K, and nearly equal for the 4 and 78 ppm. K levels. The Na content of the roots decreased as the K increased in the nutrient solution so that the Na content is much lower at 230 ppm. Na with the 78 ppm. K level as compared to the zero K level.

Field Experiment with Citrus

A small field experiment consisting of 28 single-tree plots of full grown trees has been set up to study the uptake of Na by citrus. Several

varieties of oranges and grapefruit, and one variety of Satsuma, on both sour orange and rough lemon rootstocks, are represented. On March 15, 1951, varying amounts of K were applied (0, 12, and 20 lbs. of 8% K_2O fertilizer per tree) and varying amounts of Na (0, 4½, 9, 18, and 45 lbs. of NaCl per tree) were applied at the same time. On March 20, 12 lbs. of an 8-0-0-6-2-1 fertilizer mix was applied to each grapefruit tree and 10 lbs. of the same mix was applied to each orange and Satsuma tree. All materials containing Na or K were omitted from the mix.

The various plant parts were sampled on June 26, 1951 and analyzed to determine which part would serve as the best index of Na uptake by the plant. There was no significant increase in Na content in the various parts of the trees where 4½, 9, or 18 lbs. of NaCl was applied but there was a considerable increase where 45 lbs. of NaCl was applied (Table 16). It appears that the leaves will give the best indication of Na uptake and also will be much easier to handle.

TABLE 16.—NA AND K CONTENT OF VARIOUS PARTS OF INMAN GRAPEFRUIT TREES BUDDED ON ROUGH LEMON ROOTSTOCK WITH AND WITHOUT ADDED NACL. ALL K WAS OMITTED FROM THE SPRING FERTILIZER APPLICATION.

Plant Part	45 Lbs. NaCl (No K) K Percent*	45 Lbs. NaCl (No K) Na Percent*	No NaCl (No K) K Percent*	No NaCl (No K) Na Percent*
Spring flush leaves	2.08	0.555	2.88	0.053
Old leaves (1950 flushes)	1.46	0.312	1.54	0.091
Spring flush twigs	1.71	0.024	1.65	0.020
Older twigs, up to 3/16 inch	0.96	0.024	0.83	0.024
Bark, old twigs, 3/16-3/8 inch	1.25	0.030	1.29	0.032
Wood, older twigs, 3/16-3/8 inch	0.46	0.020	0.42	0.010
Bark of twigs 3/8-5/8 inch	1.02	0.027	1.13	0.027
Wood of twigs 3/8-5/8 inch	0.42	0.013	0.42	0.005
Roots, approximately 3/8 inch	0.73	0.216	0.46	0.010
Roots, approximately 3/16 inch	0.83	0.320	0.69	0.036
Roots, ¼ inch or less, with rootlets	1.04	0.262	1.25	0.093

* Percent of the dry matter.

There was no significant difference in the analyses of samples washed in Vel and thoroughly rinsed, and those not washed.

The data in Table 16 show that the leaves and roots were definitely higher in Na in the tree receiving the 45 lb. application of NaCl but the other plant parts were not greatly affected. The K content of the spring flush leaves from the tree receiving 45 lbs. of NaCl is slightly lower than that of the tree receiving no NaCl.

On July 30, 1951, 100 lbs. of NaCl was applied to the soil beneath a Marsh seedless grapefruit tree. On August 10, definite toxicity symptoms were observed and samples were taken of various plant parts (Table 17). The toxicity symptoms observed first were a yellowing at the tips and edges of the leaves, followed by burned tips and leaf edges. There were also some burned spots in the central part of the leaves. A heavy leaf fall occurred after the appearance of these symptoms. These toxicity symptoms are very similar to the symptoms shown by a tree in sand culture to which was added no K and 230 ppm. Na from Na_2SO_4.

TABLE 17. Na and K Content of Various Parts of a Marsh Seedless Grapefruit Tree Treated with 100 Pounds of NaCl Added to the Soil Surface.

Plant Part	Na Percent	K Percent
Spring flush leaves	1.150	1.50
Old leaves (1950 flushes)	0.912	2.34
Roots (up to 1/4 inch)	0.292	0.54
Green twigs	0.438	0.67
Older twigs, up to [illegible]/16 inch	0.212	0.29

The data in Table 17 show that the Na content of all plant parts analyzed increased considerably over that found in the tree treated with 45 lbs. NaCl. The Na content of the spring flush leaves was about doubled, and that of the older leaves nearly tripled. The Na content of the larger twigs was increased about 16 times, and that of the green twigs slightly more than that. The roots showed a much smaller percentage increase. The K content decreased in the young leaves and increased in the older leaves, over that found with the 45-lb. treatment with NaCl.

SUMMARY

Although Na is not recognized as an essential element for the growth of higher plants, many crops will produce higher yields with Na as a fertilizer than without it. A review of the literature is presented covering physiological responses of various plants and yield responses of various crops to Na, and many of the theories advanced to explain the beneficial effects of Na on certain plants.

Na and K behave somewhat alike in their effect on plant growth. The amounts of K available to a plant usually affects its response to added Na.

Table beets grown in sand cultures showed large increases in yield from added Na with either 4 or 20 ppm. K in the nutrient solution, but gave no yield increase to this element with 195 ppm. K available.

Yields of celery in sand cultures increased as the K was reduced from 195 to 39 ppm. and replaced by chemically equivalent amounts of Na in the nutrient solution.

Nitrate of soda gave much higher yields of spinach than did either ammonium or calcium nitrate when each was supplied in an amount equivalent to 100 lbs. N per acre to Sassafras loam soil without added K. The increased yields are attributed to the Na carried in nitrate of soda.

Celery fertilized with nitrate of soda yielded far more than that receiving either ammonium or calcium nitrate and nearly equalled the yield of that receiving potassium nitrate.

Spinach yields in outdoor pots filled with Sassafras loam soil were significantly increased by the use of Na equivalent to either 100 or 200 lbs. K_2O per acre, when receiving no K or when fertilized with 25 or 50 lbs. K_2O per acre. Na accumulation in the conducting tissues of plants was confirmed by activity measurements and radioautographs with radioactive Na^{22}. Na^{22} was found in leaf petioles of tomato plants within 30 minutes after it was applied to the growing medium.

In preliminary studies, citrus trees were found to take up low amounts of Na except when it was furnished in high concentrations.

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SODIUM AND POTASSIUM INTER-RELATIONSHIPS IN PANGOLA GRASS

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The substitution of sodium for at least part of the potassium required for plant growth has been recognized for many years. Unfortunately we know little more about this relationship than did J. A. Turner when he wrote in the Cotton Planter's Manual of 1856 (5). "As to soda, it stands nearest in its chemical character to potash, and though it is itself not nourishment for plants, to any great extent, as the quantity of it decreases in plants in proportion to their cultivation, it nevertheless acts as a substitute for potash, in the same manner as magnesia for lime. The composition of the cotton staple, as given above shows the presence of soda in its ash in no small quantity. This circumstance seems to express, in accordance with the analysis of the soil, that by the scarcity of potash the plants were forced to assimilate soda. In this condition of things, the cotton plant could not be produced in its most perfect form."

Although this substitution is well recognized, many plant physiologists consider sodium as a non-essential element except for certain exceptional plants that normally grow along sea coasts or other salty soil habitats (1). Some of the so-called plant responses to sodium can probably be attributed to secondary effects such as changes in soil structure or substitution of sodium for potassium on the clay mineral which releases more potassium to the plant. Responses to this element are frequently reported under conditions of low potassium supply (2, 3). When potassium supplies are adequate, sodium responses are not as frequent, but some responses have been obtained on cotton plants that were considered to be adequately supplied with potassium and other nutrients. (4).

In the winter of 1949-1950 a preliminary experiment was conducted in the greenhouse using virgin Leon fine sand in which white clover and Pangola grass were grown together in 2-gallon pots with adequate fertilization and lime except that in certain of the cultures one-third, two-thirds, and all of the potassium was replaced by equivalent amounts of sodium. It was observed that the clover was progressively poorer on the higher sodium levels and developed the usual symptoms of potassium deficiency while the Pangola grass grew well over the entire range of sodium levels and actually produced more dry weight on the all-sodium level, although this was attributed to the lack of competition from the clover.

Since many Florida soils in pastures were known to be inadequately supplied with potassium, two pot experiments were planned (Table 1) to investigate the substitution of sodium for potassium in Pangola grass more thoroughly. The first experiment was designed to show responses to potassium levels and to chemically equivalent quantities of sodium supplied alone and with potassium. The second experiment was designed to show the effects of sodium, potassium, calcium, and ammonium as cations when equivalent amounts of nitrogen were supplied as top dressings to pastures that had been fertilized at slightly better than average

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rates. The effects of rates of lime and high calcium supplied as calcium chloride were also included in this experiment. Demineralized water applied to the surface of the pots was used throughout the experiment.

TABLE 1.—PANGOLA GRASS. GREENHOUSE EXPERIMENTS, WINTER 1950-1951.

Experiment I. Substitution of Na for K.

Basic treatment in 2 gal. pots of virgin Leon fine sand 0-6 inch
 2000 lbs. lime/A = 7.3 gms. dolomite/pot.
 500 lbs. superphosphate/A = 1.8 gms. superphosphate/pot

Na and K variations (3 Replications):

1.	0 lbs. K/A +	0 lbs. Na/A =	0 gms. KCl +	0 gms. NaCl/pot.
2.	0 lbs. K/A +	78 lbs. Na/A =	0 gms. KCl +	.27 gms. NaCl/pot.
3.	0 lbs. K/A +	157 lbs. Na/A =	0 gms. KCl +	.54 gms. NaCl/pot.
4.	100 lbs. K/A +	0 lbs. Na/A =	.35 gms. KCl +	0 gms. NaCl/pot.
5.	100 lbs. K/A +	78 lbs. Na/A =	.35 gms. KCl +	.27 gms. NaCl/pot.
6.	100 lbs. K/A +	157 lbs. Na/A =	.35 gms. KCl +	.54 gms. NaCl/pot.
7.	200 lbs. K/A +	0 lbs. Na/A =	.7 gms. KCl +	0 gms. NaCl/pot.
8.	200 lbs. K/A +	78 lbs. Na/A =	.7 gms. KCl +	.27 gms. NaCl/pot.
9.	200 lbs. K/A +	157 lbs. Na/A =	.7 gms. KCl +	.54 gms. NaCl/pot

Nitrogen to be supplied as required as NH_4NO_3 at same rates and times as Experiment II.

Experiment II. Na, K, Ca, and NH_4 as cations in nitrate applications

Treatments in 2 gal. pots of virgin Leon fine sand 0-6 inch.
 500 lbs. superphosphate/A = 1.8 gms. superphosphate/pot.
 150 lbs. muriate of potash/A = .52 gm. KCl/pot.

Variations (2 Replications)—each variation to get separate top dressings of Na, K, Ca, and NH_4 nitrates, nitrogen to be equivalent to 100 lbs/A $NaNO_3$.

 0 lbs. lime/A = 0 gms. $CaCO_3$/pot.
 2000 lbs. lime/A = 7.3 gms. $CaCO_3$/pot.
 4000 lbs. lime/A = 14.6 gms. $CaCO_3$/pot.
 100 lbs. $CaCl_2$/A = 3.6 gms. $CaCl_2$/pot.

5 ml/pot of the following solutions are N equivalent of 100 lbs/A $NaNO_3$
 73 gms. $NaNO_3$/L
 96 gms. KNO_3/L
 35 gms. NH_4NO_3/L
 88 gms. $Ca(NO_3)_2 \cdot 4H_2O$/L

Log of Experiments.

Basic fertilizer put in pots and plants started December 15-16, 1950.
Plants established at 5 sprigs per pot thru January 8, 1951.
First N application and 1 ml. Hoaglands A to Z minor element soln. January 8, 1951.
First cutting 2-5-51.
Second N application 2-8-51.
Second cutting 3-2-51.
Third N application 3-2-51.
Third cutting 4-2-51.
Fourth N application 4-2-51 (double rate of application).
Fourth cutting 5-8-51.
Fifth N application 4-9-51 (double rate of application).
Fifth cutting 6-19-51 (experiments terminated).
Soil samples taken from pots 7-27-51 (R-1122).

The grass was cut back to the level of the top of the pots (about one inch above soil surface) once a month and nitrogen reapplied at a rate equivalent to 100 pounds per acre of nitrate of soda. After the third cutting it was obvious that this rate of nitrogen was inadequate to take care of the rapid rate of growth and the nitrogen application was doubled.

TABLE 2 PANGOLA GRASS NA-K EXPERIMENTS - GREENHOUSE 1950-51 TOTAL YIELDS OF FIVE CUTTINGS IN GMS./POT.

Experiment I

Treatments	0 Na	1 Na	2 Na	Totals K
0 K	16.97	23.96	36.98	
	14.66	21.85	24.63	
	15.28	22.91	23.55	
	46.91	68.72	85.16	200.79
1 K	24.46	32.04	40.31	
	26.99	38.99	36.59	
	28.13	32.31	34.45	
	79.58	103.34	111.35	294.27
2 K	33.45	40.10	44.55	
	37.60	39.63	45.12	
	34.47	38.51	48.23	
	105.52	118.24	137.90	361.66
Totals Na	232.01	290.30	334.41	

L.S.D. for Na and K totals = 41.84 at 1% level.
(gms./pot x factor 275 = lbs./acre.)

Experiment II

Treatments	0 Lime	1 T Lime	2 T Lime	1000 Lbs. $CaCl_2$	Total NO_3 Carriers
KNO_3	60.59	58.18	67.07	61.66	
	57.79	60.02	66.39	69.40	
Sums	118.38	118.20	133.46	131.06	501.10
$NaNO_3$	48.27	52.54	48.52	46.48	
	53.25	58.44	52.37	50.87	
Sums	101.82	110.98	101.39	97.35	411.24
$Ca(NO_3)_2$	44.64	34.78	35.91	26.53	
	32.08	35.53	38.61	25.74	
Sums	76.70	70.31	74.52	52.27	273.80
NH_4NO_3	35.06	34.36	33.10	28.02	
	37.21	35.81	38.59	27.33	
Sums	72.27	70.17	71.69	55.35	269.48
Totals Lime	368.87	369.66	381.06	336.03	

L.S.D. for NO_3 carrier and lime totals 40.47 at 1% level.
29.22 at 5% level.
L.S.D. for interaction sums 20.23 at 1% level.
14.61 at 5% level.

The rates of growth in the first experiment followed the rates of potassium and sodium application very closely from the start. Characteristic potassium deficiency symptoms, thin stems, narrow leaves and burning of the lower leaves, appeared almost at once in the pots receiving no potassium or sodium and developed progressively through the potassium and sodium levels so that these symptoms were present in the high sodium-potassium culture at the final cutting. Unusually early bloom was also noted in the pots receiving no potassium or sodium. The yield summary in Table 2 shows that under the conditions of the experiment sodium and potassium both caused highly significant yield increases. No significant interaction of sodium and potassium was found under the conditions of this experiment. It is possible that the increases in dry weight due to sodium and potassium are mutually additive.

In the second experiment there was little difference in the growth of the first two cuttings except that there was some lag in the calcium chloride pots. The high salt content in these pots made it difficult to get the grass sprigs to root and this slow start resulted in reduced yields which may not be directly comparable to the lime and check treatments. The early clippings removed much of the original potassium application and in the last three clippings the yield pattern was much the same as shown for total yields in Table 2. In later cuttings the $Ca(NO_3)_2$ and NH_4NO_3-treated plants developed characteristic potassium deficiency symptoms of thin stems and narrow leaves and burning of the lower leaves. The $NaNO_3$-treated plants continued to produce thick stems and broad leaves of normal plants but prior to the last cutting developed potassium deficiency symptoms which appeared as a lighter shade of green over the entire plant and some lower leaf burn. Normal growth continued on the KNO_3-treated plants.

As a dry weight producer KNO_3 was a superior top dressing for Pangola grass. $NaNO_3$ gave about 20 percent less, whereas $Ca(NO_3)_2$ and NH_4NO_3 produced only about one-half the dry weight of the KNO_3 treatment. Lime levels had little effect on dry weight production although some depression was caused by $CaCl_2$ on the $Ca(NO_3)_2$ and NH_4NO_3 treatments.

Chemical analyses for potassium, sodium, calcium and phosphorus in the last cutting are given in Table 3. The potassium and sodium supplies in the first experiment were nearly exhausted although the pattern of sodium and potassium application was still reflected in the quantities of these elements in the plant tissue. Calcium, magnesium, and phosphorus values are approximately inversely proportional to the amount of dry weight produced at this cutting.

In the second experiment the effects of the extra sodium and potassium are clearly apparent. High potassium depressed sodium, calcium, and magnesium content in the herbage and high sodium depressed potassium, calcium, and magnesium. The $NaNO_3$ applications did not depress the calcium content of the herbage to the same extent as equivalent applications of KNO_3 in this cutting. In earlier cuttings the depression of calcium by KNO_3 and $NaNO_3$ were of the same order of magnitude. (It was necessary to analyze the plant tissue from the $NaNO_3$ treatments for calcium by the oxalate method because the high sodium content interferes in the flame photometer procedure.) The phosphorus values again seem

largely to reflect the rate of growth, the KNO_3-treated plants containing the least and the NH_4NO_3-treated plants containing the most phosphorus.

TABLE 3.—Pangola Grass Na-K Experiments. Greenhouse 1950-51 Analysis of Fifth Cutting Composite Expressed as mg/gm Dried Tissue.

Experiment I

Treatment K	Treatment Na	Sample No.	K	Na	Ca	Mg	P
0	0	P-431-1	3.8	2.0	13.0	4.50	2.25
0	1	2	1.9	2.3	12.5	2.10	1.95
0	2	3	2.5	4.3	11.8	2.28	1.26
1	0	4	3.3	1.5	11.0	3.30	1.70
1	1	5	2.5	2.0	11.8	2.28	1.10
1	2	6	2.5	3.5	10.3	1.63	1.03
2	0	7	3.3	1.5	10.3	3.30	1.20
2	1	8	3.3	2.5	9.5	2.85	1.03
2	2	9	2.5	4.8	8.8	1.93	.83

Experiment II

Lime		Sample No.	K	Na	Ca	Mg	P
0	K	29	16.3	1.3	2.5	1.00	.60
0	Na	30	2.5	15.3	6.3	.88	.98
0	Ca	31	3.8	1.8	10.3	2.85	.93
0	NH_4	32	3.3	1.3	4.8	4.00	1.33
1	NH_4	33	2.5	1.5	11.8	4.00	1.33
1	Ca	34	3.3	1.3	11.0	3.52	1.10
1	Na	35	3.3	12.5	6.5	1.15	.70
1	K	36	16.3	1.3	3.0	.88	.45
2	Ca	37	3.3	1.3	10.3	2.85	.85
2	K	38	14.5	1.0	2.5	.88	.45
2	NH_4	39	3.3	1.8	11.8	2.85	1.10
2	Na	40	1.9	14.3	6.3	1.00	.70
Cl	Na	41	2.5	18.5	7.0	1.00	.98
Cl	NH_4	42	4.4	2.0	8.8	1.93	3.32
Cl	K	43	16.8	1.3	2.5	.88	.55
Cl	Ca	44	4.4	2.0	10.3	1.48	2.80

Analyses of the earlier cuttings are not tabulated here but similar trends were noted. As would be expected the earlier the cutting the higher the sodium and potassium percentages. It was evident that some luxury consumption of sodium and potassium in the early cuttings resulted in an early depletion of these elements in the soil and subsequently reduced dry weight production in later cuttings.

Soil analyses at the end of the experiments showed less than 10 ppm. each of sodium and potassium present in all pots except where these elements had been added with the nitrate. Residues of sodium and potassium, where these elements had been applied in the top dressing, were variable, ranging from 10 to 60 ppm. of the element applied. Minimum exchangeable calcium in the no-lime pots at the end of the experiment was 230 ppm.

Table 4 shows the effects of these treatments on the nitrogen content of the herbage. The trend is toward a lower percentage of nitrogen in the herbage with increased growth. Nearly all the nitrogen added was

TABLE 1. PANGOLA GRASS Na-K EXPERIMENTS, GREENHOUSE, 1950-1951.

Treatment K	Treatment Na	Sample No.	Percent Nitrogen in Oven Dried Herbage: 1st & 2nd Cutting P-409	3rd Cutting P-113	4th Cutting P-426	5th Cutting P-431	Total N Removed in mgs. per Pot: 1st & 2nd Cutting P 109	3rd Cutting P-113	4th Cutting P-126	5th Cutting P-131	Grand Total
			Experiment I								
0	0	1		1.50	2.20	2.01		59.5	16.9	125.8	232.2
0	1	2	2.43	1.03	1.77	1.86	129.8	59.3	16.1	171.1	406.6
0	2	3	3.31	.95	1.41	1.47	185.9	58.6	70.9	176.6	193.0
1	0	4	2.52	.90	1.41	1.57	117.0	61.0	52.3	160.1	420.1
1	1	5	2.12	.85	.93	1.06	114.9	55.9	62.2	152.1	115.1
1	2	6	2.15	.85	.90	1.01	153.0	61.0	76.7	119.8	113.5
2	0	7	1.78	.79	.90	1.10	113.0	60.1	67.0	151.5	391.6
2	1	8	2.27	.75	.86	.95	111.5	61.5	88.7	134.3	432.0
2	2	9	2.30	.79	.75	.70	157.8	65.8	80.1	110.5	441.5
			Experiment II								
Lime											
0	K	29	1.99	.80	.76	.48	116.0	56.1	95.1	151.9	152.7
0	Na	30	2.14	.79	.74	.70	138.8	58.1	100.7	166.0	463.9
0	Ca	31	2.58	1.00	1.08	.84	192.8	63.5	51.7	163.5	471.5
0	NH_4	32	2.31	.83	1.12	.85	157.0	53.8	68.7	112.2	121.7
1	NH_4	33	1.90	.78	1.04	1.08	104.3	57.3	69.1	168.6	399.3
1	Ca	34	1.84	.76	.89	1.02	96.0	50.2	75.2	152.0	373.4
1	Na	35	1.96	.87	.80	.73	188.7	51.1	80.5	215.8	539.1
1	K	36	2.29	.79	.81	.52	165.9	65.8	100.9	161.7	491.3
2	Ca	37	1.82	.86	.84	.78	110.2	15.9	62.1	143.9	362.1
2	K	38	2.12	.82	.76	.46	172.3	65.2	105.1	169.2	511.8
2	NH_4	39	2.10	.78	1.07	1.00	122.2	52.9	73.4	163.8	412.3
2	Na	40	2.11	.78	.92	.73	113.8	68.5	105.7	188.9	506.9
Cl	Na	41	2.38	.84	.82	1.01	118.2	74.2	101.2	237.8	531.1
Cl	NH_4	42	2.69	1.01	1.74	2.00	119.7	98.5	97.3	157.8	473.3
Cl	K	43	2.31	.86	.73	.11	126.3	93.6	113.9	117.9	481.7
Cl	Ca	41	2.50	.97	1.13	1.17	105.8	68.2	70.6	116.1	390.7
			Nitrogen added per pot in mgs.				120	60	120	120	120

recovered in the herbage even under acute potassium deficiency and some additional nitrogen was recovered from the soil under the optimum conditions of the experiment.

CONCLUSIONS

Under greenhouse conditions sodium will substitute for a large percentage of the potassium requirements in Pangola grass. Because of the usual low level of available potassium and sodium during the summer months in Florida soils under pasture conditions it is probable that at least on Pangola grass more dry weight per pound of nitrogen fertilizer used will be obtained if sodium or potassium or both are applied with the nitrogen. The percentage nitrogen in the herbage may be controlled to a limited extent by the quantities of sodium and potassium applied with the nitrogen or available in the soil at the time of the nitrogen application.

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SYMPOSIUM: SOURCES AND RATES OF LIMING

GEOLOGY AND LOCATION OF LIME SOURCES IN FLORIDA

J. L. CALVER*

Limestone production statistics are gathered annually by the U. S. Bureau of Mines in cooperation with the Florida Geological Survey. The latest data available, those for the year of 1949, show that commercial limestone was produced from forty quarries located in eleven counties in Florida. In distribution these counties fall naturally into four areas, with Jackson County representing the northwestern portion of the State, Alachua, Levy, Marion, Citrus, Sumter, Hernando and Pasco counties representing the central portion and, in South Florida, dolomite in Sarasota and Manatee counties on the northwest and limestone in Dade and Broward counties on the southeast. These forty quarries, for which data were submitted to the U. S. Bureau of Mines, produced over 4,200,000 short tons of limestone in 1949, which had a value in excess of $4,700,000.

The use in which the greatest tonnage of limestone was consumed is classified under the heading: *concrete and road metal.* For these purposes, 3,067,000 short tons valued at approximately $3,510,000 were sold during 1949, and that quantity represents 73 per cent of the total crushed limestone production. The remaining 27 per cent was divided approximately as follows: *Railroad ballast* consumed nearly ten per cent; *road base* materials eight and one-half per cent; and *non-commercial* uses—that material produced by county and city units and used primarily for road base and road metal—amounted to less than five per cent. Thus the limestone entering into concrete, road metal, railroad ballast and road base uses accounts for approximately 97 per cent of the entire production of crushed limestone. Agricultural limestone, riprap, fertilizer filler and other minor uses shared in only three per cent of the State's total production. The exact totals for these uses are not available because of the policy adopted by the U. S. Bureau of Mines to avoid disclosure of production data from individual operations.

The quantity of limestone used in the manufacture of cement, together with that entering into the production of burned lime have been excluded from the before-mentioned production data. The tonnage and value of limestone for these purposes normally are included in data on cement and lime production. These industries, however, have only one or two producers in the State and, unless each company gives its approval, disclosure of the individual company's production data is avoided. It may be interesting to mention, nevertheless, that about 8 per cent of the hydrated lime manufactured in the State in 1949 was consumed in agricultural uses.

With this introduction, I would like to outline briefly the geology of the State and to point out in particular the relationships found in the limestone-producing areas already briefly mentioned and shown in quite a generalized way on the map of figure 1.

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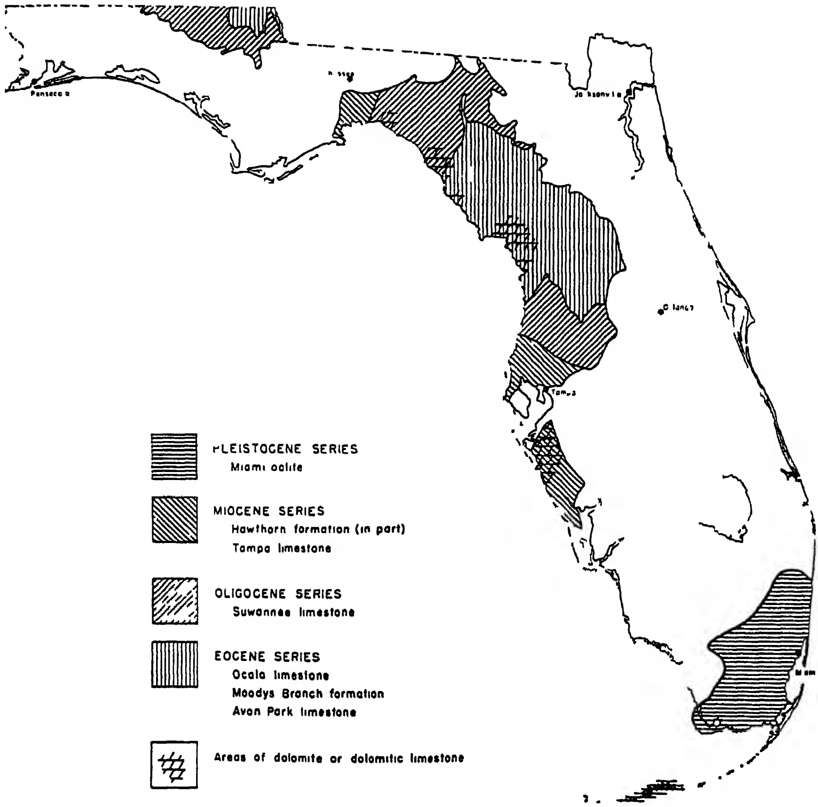

Figure 1.—Generalized map showing surface distribution of various limestones and dolomites in Florida.

Situated wholly within the Coastal Plain Province, Florida is underlain by 4,000 feet or more of sedimentary rocks that overlie a basement of older sedimentary, metamorphic and igneous formations. The oldest rock exposed at the surface of the State is considered by geologists to be quite young; it is the Avon Park limestone of Middle Eocene age. This formation, together with the Ocala limestone, Upper Eocene, and the still younger formations of the Oligocene, Miocene, Pliocene, Pleistocene and Recent Epochs represent a stratigraphic section of approximately 1,800 feet. Sedimentary rocks older than the Middle Eocene limestones do not crop out and are known in Florida only through cuttings, cores, and records of wells that penetrate them. These subsurface formations include the rocks assigned to the Lower Eocene, Paleocene of the Cenozoic system, as well as those of the Mesozoic, Paleozoic and Pre-Cambrian systems.

The early Cenozoic and Mesozoic formations range in thickness from 2800 feet in the northern part of the Peninsula to more than 15,000 feet in the region of the Florida Keys. In Western Florida, these formations are somewhat thicker and range from 8,400 feet in Jackson County to an estimated 15,000 to 20,000 feet in Escambia County. The older subsurface

strata of the Paleozoic system are not less than 3,000 feet in thickness and may be as much as 6.000 feet. Because all of these older sediments. as well as the crystalline rocks of possible Pre-Cambrian age do not come to the surface anywhere within the State. the sequence of events that make up their history is not of primary interest to either the producers or the consumers of limestone which is obtained from quarries in the surface formations. Furthermore. the structures developed in the Cretaceous and older rocks bear little, if any, relationship to the structures in the younger sediments that have been outlined by surface studies and detailed by well penetrations.

There are several structures in the uppermost and younger sedimentary rocks of the Floridian Plateau that are significant in bringing limestone formations near the land surface. The most important of these is the Ocala Uplift in which the Eocene and younger sediments are arched into a broad doubly plunging anticline that trends northwest-southeast. This fold may be traced from Madison County southward to Hardee County. It is along the crest of this fold in the central and southern portions of Levy County that the Avon Park limestone, the oldest sedimentary rock exposed in Florida, is found. Surrounding the outcropping of this chalky limestone are other Eocene limestones: the Moodys Branch formation and the Ocala limestone. The Moodys Branch formation is a nearly pure limestone of about 80 feet in thickness that has been separated from the base of the Ocala limestone, which has a maximum thickness of 360 feet, in recent studies by the Florida Geological Survey. These Eocene formations on the flanks of the fold dip at low angles toward the Atlantic Ocean and the Gulf of Mexico. It is this broad, gentle arch known as the Ocala Uplift that brings the Eocene limestone close to the land surface in the central part of the State.

At many places within this anticlinal structure in Alachua, Levy, Marion, Citrus, Sumter and Hernando counties, the Ocala limestone has been extensively quarried, particularly in the vicinity of Ocala. For the most part this limestone has a uniform texture that allows ready crushing and pulverizing; it is generally free from grit and its chemical purity approaches that of the chemical formula for the mineral calcite, i.e., 100 per cent $CaCO_3$. The Ocala limestone will meet the most exacting chemical specifications for high calcium stone. In spite of its purity, this limestone enters into many common uses which include road base material. road metal, railroad ballast, agricultural lime. concrete aggregate, etc. It is also used in the manufacture of quick and hydrated lime.

Because of the southward regional dip of the rock strata, the Eocene limestones are not found exposed south of the Hernando-Pasco county-line. In these counties, limestone formations that occur above the Ocala limestone, the Suwannee limestone of Oligocene age and the Tampa limestone of Miocene age, are found near the land surface. The Suwannee limestone varies in character from a hard, resonant limestone to a soft, granular limestone that contains some silica; the Tampa limestone also may be hard and massive and contain impurities of clay and sand. Both of these formations have been quarried so extensively in the vicinity of Brooksville, Hernando County, that the name "Brooksville Stone" is often used to designate these limestones which are used for cement manufacture, railroad ballast and concrete aggregate.

Further to the south in Manatee and Sarasota counties, Miocene strata contain limestones belonging to the Tampa limestone and the Hawthorn formation. Outcrops of these formations, particularly in the western portions of the counties, are here composed of dolomite or dolomitic limestone. Agricultural lime is produced in the vicinity of Samoset, Manatee County, and of Sarasota, Sarasota County, from dolomitic limestones that are early or possibly middle Miocene in age.

Dolomite and dolomitic limestones are also found in Dixie, Levy, and Citrus counties. The upper portion of the Avon Park limestone is represented in some areas by dolomitic rock and the quarry at Lebanon, Levy County, is in a dolomite facies of this formation. In northern Citrus County, the Moodys Branch formation contains some poorly consolidated dolomitic rock which is quarried in the vicinity of Red Level. Dolomites and dolomitic limestones also occur in western Dixie and southern Taylor counties as a facies of the Ocala limestone; however, quarries have not been developed in these areas.

In western Florida, there is another gentle fold in the series of younger sediments that form the surface rocks of the State. This structure passes into Jackson County and is the southern extension of an anticline known as the Decatur Arch. The middle Eocene limestones are again brought to or near the land surface in Jackson, Holmes and Washington counties, and the Ocala limestone is quarried in Jackson County. Huge reserves of high grade limestone exist in not only Jackson County, but also in Holmes and Washington counties, and structurally the area is quite similar to that of the Ocala uplift.

The remaining limestone sources in the State, particularly those in South Florida, are very young, geologically speaking. They were formed, for the most part, during the Ice age or Pleistocene epoch. From a commercial quarrying point of view, the most important of the several formations that have been mapped in southern Florida, is the Miami oolite. Generally, this formation is a comparatively soft, white limestone composed of small spherical grains called oolites. It is found at or near the land surface in a broad band that extends along the East Coast from approximately the Palm Beach-Broward county-line to Key West. This rock is quarried extensively in the vicinity of Miami where it is the main source of commercial limestone. The crushed limestone produced in Dade County constituted more than 55 per cent of the crushed stone produced in Florida during the year of 1949.

This discussion of lime sources in Florida would be incomplete without mention of the shell facies of the Anastasia formation. This Pleistocene formation is found at or near the surface in a narrow belt along the East Coast from Anastasia Island, St. Johns County, to near the Palm Beach-Broward county-line where it may be traced into a transitional zone of shell marl and sandy limestone that merges southward into the Miami oolite. The most conspicuous part of the Anastasia formation is coquina, a rock composed of whole or broken shells that are more or less firmly cemented together. It is well known that the harder portions of coquina rock make an attractive and durable building stone and that the softer portions, which may contain considerable quartz sand, are used for concrete aggregate, in the manufacture of concrete products and in road building. Crushed coquina has been used in the past for agricultural lime and pulverized coquina for stock feed and chicken grit. A large

and extensive utilization of coquina will begin with the operation of the new cement mill located near Flagler Beach, Flagler County. Here the Lehigh Portland Cement Company now has under construction a cement mill which has a designed capacity of 1,400,000 barrels annually.

LIMING MATERIALS

GAYLORD M. VOLK *

Liming materials are used for the counteraction of excess soil acidity. Ground limestones are used to the greatest extent for this purpose, with hydrated lime next in volume. A limited amount of burned or quick lime, soft marl, shell marl, quarry run soft lime rock, and certain industrial by-products are used locally or for special purposes.

Ground agricultural limestone can be classified either as high calcic limestone or as dolomite in most instances. High calcic limestone usually contains 85 to 100 percent of calcium carbonate with somewhat less than 10 percent of magnesium carbonate present. The dolomite consists of a mixture of calcium carbonate and magnesium carbonate in which the calcium carbonate makes up not over 63 percent of the carbonates and the magnesium carbonate between 37 and 46 percent. There are no established limits for these materials, but naturally occurring limestones more or less fall into such a grouping. When limestones were deposited in past geologic times, two ranges in the calcium carbonate-magnesium carbonate predominated. At one end of the range the high calcic limestones containing less than 10 percent of magnesium carbonate were deposited. Beyond this there was a big jump in the ratio of calcium to magnesium and the next range of deposition came where magnesium carbonate made up from 37 to 46 percent of the carbonates present. Above this there was very little deposition of limestone in any form. Table 1 shows how well this system is substantiated by materials submitted for sale in Florida.

TABLE 1.—REPRESENTATIVE ANALYSES OF AGRICULTURAL GROUND LIMESTONE USED IN FLORIDA IN 1950.

(From eight different sources in Florida, Georgia and Alabama)

Calcium Carbonate %	Magnesium Carbonate %	Moisture %	Passing 60 Mesh %	Passing 20 Mesh %
		High Calcic Limestone		
89		2	12	78
92		3	31	19
92		1		
		Dolomite		
51	37	5	63	95
54	41	1	65	85
56	37	3	70	97
58	36	2	74	97
59	35	2	55	73

The Commercial Fertilizer Law of Florida states as follows: "Limestone shall be guaranteed on the basis of Calcium Carbonate ($CaCO_3$) and

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Magnesium Carbonate ($MgCO_3$) and in addition shall be guaranteed on a screen test."

The screen test consists of determining the percentages of the material that will pass 60 mesh and 20 mesh sieves, and is so reported on the tag. The finer the material, the more rapid is its reaction with the soil. Fine materials can be made to come in contact with a greater portion of the soil mass and react more completely with the soil acidity. Coarse particles will neutralize the acidity in their immediate vicinity and must then wait either for tillage to rearrange them against fresh soil or for the slow reaction with acidity lying at a distance to take place. Generally it is not desirable to have all very fine material, but to have a graded material containing a range of particle sizes. The coarser material that will react more slowly will continue to maintain the soil pH as new acidity develops from fertilization and associated practices. This permits heavier, more economical applications at one time without increasing the danger of overliming. Agricultural limestone usually has a fineness such that about 85 percent passes a 20 mesh and 60 percent passes a 60 mesh sieve. This makes a good mixture of particle sizes for general use. Finer grades often are called "Pulverized" and "Superfine", and coarser grades called "Meal" and "Screenings." As can be seen from Table 1, ground dolomite submitted for test in Florida has a screen test about as given above for ground agricultural limestone. Our high calcic limestone derived from soft rock formations is somewhat coarser by screen test. This probably is a desirable difference between the materials because high calcic limestone reacts faster than dolomite.

Schollenberger and Salter (1) have published an evaluation chart for ground limestone intended to show how much of the applied lime would be used by the soil in a given period of time. According to the chart the materials listed in Table 1 would have approximately the following activities:

EFFICIENCY

(Amount used by soil acidity)

Time	*Dolomite*	*High Calcic*
3 months	42%	48%
1 year	67%	69%
4 years	80%	78%
16 years	85%	82%

It is assumed that the above values were obtained on soils of about a silt loam texture, and are the result of addition of a reasonable application to an acid soil.

Tests by Volk and Bell (2) showed that about one-third of a high calcic lime was used by soil acidity the first year after incorporation in three highly acid flatwoods soils. The amount of lime applied was sufficient to bring the pH up to 6.0 in one year. It was incorporated in the six inch surface layer of soil and kept undisturbed after incorporation. This rate is about one-half of that to be expected from the chart mentioned above.

Much lime is now being used for surface application to pastures. The rate of penetration is important because this markedly influences nitrification and retention of other fertility elements as well as supplying calcium.

Tests showed no significant differences in rates of penetration of high calcic limestone, dolomite, or hydrated lime. Penetration into acid soil was very slow. When a heavy application of lime was applied only to the surface instead of being incorporated, it raised the pH of the immediate subsurface at the one inch depth only two-tenths of a pH unit. This same amount of lime incorporated throughout the surface six inches would have raised the soil pH from the virgin pH of about 4.3 up to approximately pH 6.1. From this it is estimated that lime will not effectively penetrate over one inch per year regardless of the source used. Apparently the pH of a layer of soil must be 6.0 to 6.5 before lime will neutralize deeper layers below it.

Hydrated lime and quick lime, made by burning high calcic limestone, have a neutralizing value such that about 1500 pounds of hydrate or 1100 pounds of quick lime are equal to a ton of high calcic lime. They react very rapidly with the soil. In addition to the above there are two products obtained by burning dolomite. One product sold in the oxide form contains about 42 percent magnesium oxide and 58 percent calcium oxide. The other is similar except that the calcium oxide has been converted to hydrated lime but the magnesium remains as the oxide. These materials are for special uses where quick action and a source of magnesium are desired. The availability of the magnesium apparently lies between that of soluble magnesium and dolomite.

Shell refuse, shell marl, soft marl, and by-product lime from water treatment all are good liming materials if applied dry and in accordance with their screen tests. Cyanamid and basic slag have liming value, but their cost must be borne largely by the need for the other elements carried. Raw rock phosphates have negligible liming value.

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EFFECTS OF LIME ON PLANT NUTRIENT EFFICIENCY

WILLIAM K. ROBERTSON *

The effects of lime on the physical properties of the soil are not as important in Florida as elsewhere because of the sandy nature and the low clay content of Florida soils. However. liming may affect the availability of plant nutrient elements in these soils by chemical reaction and microbiological activity. The pH determination is used to evaluate the effect of lime on soil acidity since in normal soils calcium is the principal element on the base exchange complex.

In heavy clay soils the nearer the reaction is to neutral the more favorable in general are the tilth, permeability and friability of the soil. Maximum crop growth cannot be obtained unless these properties are at their optimum for root feeding. Highly acid or highly alkaline conditions promote puddling and impermeability which decrease root penetration and nutrient uptake.

Although all plant nutrient elements are of equal importance for optimum plant development, the much talked of major elements, nitrogen. phosphorus and potassium. followed by the equally important minor elements, molybdenum, boron. zinc. copper and manganese. will be considered in the order mentioned. Other elements known to be essential for nutrient balance will not be discussed because of the small amount of information available at this time.

NITROGEN

A large fraction of applied nitrogen may not be utilized by the crop but actually lost. If nitrogen is applied as the nitrate it dissolves readily in the soil solution and losses are predominantly in the drainage water. If nitrogen is applied in the ammonium form, it may be oxidized to nitrates and subjected to leaching. leached out as ammonia or volatilized as ammonia. In the latter case calcium level (pH) plays a very important role in determining the amount of applied nitrogen that is available to the plants.

Volk and Bell (18) treated seven Florida soils with ammonium nitrate and subjected them to leaching. They found where the exchange capacity was high, ammonia lost in the drainage water and that lost by volatilization was negligible up to pH 7.2. It was also found by other workers (6) that heavy soils could retain 95 to 100 percent of the nitrogen in anhydrous ammonia even when 600 pounds of nitrogen per acre were applied.

On acid soils of low exchange capacity quite different results were obtained. In the same experiment mentioned above, Volk and Bell (18) found that sandy soils lost considerable ammonia by leaching at low pH levels and little to none where the pH approached neutrality. Martin and Chapman (9) applied ammonium hydroxide to acid soils of low exchange capacity and found that when the pH was raised into the alkaline range. considerable ammonia was lost by volatilization.

From these data it would seem that in Florida where the rainfall is heavy, ammonium forms of nitrogen have an advantage over the nitrate

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form since they are less readily leached. However, the ammonium form should only be applied when the pH is higher than 5.5. If the pH is more acid than this, in addition to greater loss as ammonia, nitrification might not be adequate to supply the nitrate nitrogen plants need. The rate of nitrification of an ammonium source of nitrogen increases with the pH and is at a maximum between 6.5 and 7.5 (19). It is possible at these high pH levels that nitrification be so much in excess of plant requirement that the advantage due to the better retention of the ammonium form is soon lost.

Regardless of the source, ammonium or nitrate, the farmer should strive to apply his nitrogen at a time, in a place with relation to the roots and in a quantity such that there will be a minimum of delay between time of application and uptake by the plants.

PHOSPHORUS

Acid conditions are not favorable for effective utilization of phosphorus. Neller and co-workers (10) applied 2000 pounds of rock phosphate to Immokalee fine sand, a flatwoods soil, and tested the effect of lime on phosphorus retention, in the upper 3 inches of soil, over a period of years. Their results shown in Figure 1 indicate that without lime one-half of the phosphorus was lost whereas with lime the loss was reduced to approximately one-eighth. They suggested that the added phosphorus was leached out of the surface layer in solution and in colloidal form. In the acid upland soils, where there are higher concentrations of iron and aluminum, phosphorus is fixed as iron and aluminum phosphate. Liming these soils converts the insoluble phosphates to the more readily available calcium phosphate. In many cases liming causes enough phosphate to be made available to restore normal growth (15). The increased availability of phosphorus due to lime may be partially attributed to the creation of more favorable conditions for microbial activity which make possible the conversion of organic phosphorus to available forms.

It has been found that insufficient quantities of lime do not increase phosphorus uptake to any extent. Robertson (14), growing Camellia oats on five different Florida soils did not get any significant difference in phosphorus uptake between application rates of 500 and 1000 pounds of lime per acre. Volk and Bell using Norfolk fine sand found that the Truog phosphorus did not vary much when the pH was raised to approximately 5.5 (18).

If the lime added is sufficient to raise the pH much over 7, more and more of the less soluble tricalcium phosphate begins to form and the plants may suffer for lack of phosphorus.

The most important groups of phosphate compounds present in soils in order of their availability are as follows: (1) Calcium and magnesium phosphate, (2) Organic phosphorus compounds (phytin, nucleotides and lecithin), (3) Iron and aluminum phosphates, and (4) Apatite (17). To create favorable conditions for the available forms of group 1 to occur it is necessary to lime to about pH 6.5. This is also within the range of optimum microbial activity which would convert group 2 to available compounds and it is above the pH at which the insoluble iron and aluminum phosphates occur in quantity. Since group 4 (apatite) is practically insoluble at any reaction at which plants grow, it need not be considered in connection with liming. From this it appears that calcium should be

added to acid soils to the extent that about 75 percent of the exchange capacity is saturated for maximum use of phosphorus.

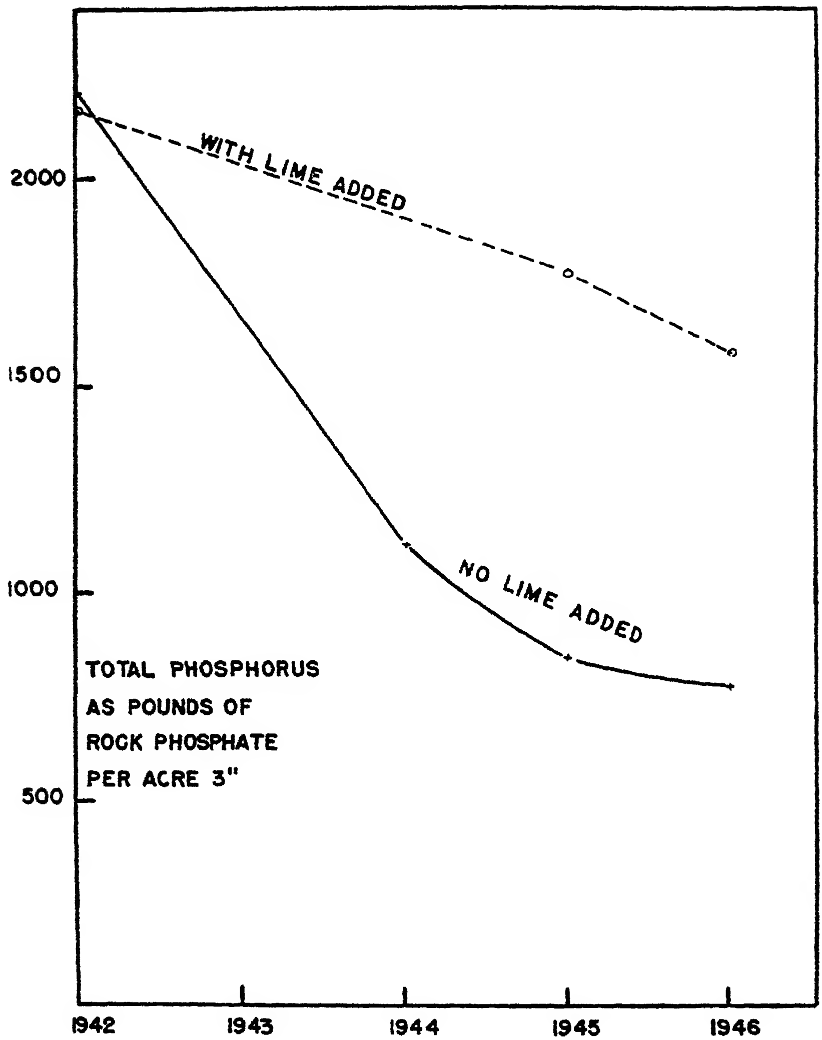

Figure 1.—Effect of liming an Immokalee fine sand pasture upon the rate of loss of phosphorus of rock phosphate from the surface three inches. Ground calcium limestone at one ton per acre was added in 1942 and again in 1943. Neller, Jones, Gammon, Nathan and Forbes (10).

When highly ammoniated superphosphate is used in mixed fertilizers with lime as a filler and when the fertilizer is stored for a month or more there results a conversion of the readily available mono-calcium and di-calcium phosphates to the less available tri-calcium phosphate. This conversion can be minimized by using ammoniated superphosphate with

a lower percentage ammoniation and by spreading the fertilizer immediately after mixing it with the lime.

POTASSIUM

The most important sources of potassium for absorption by plants are: (1) directly from the fertilizer band, (2) from the soil solution, and (3) from the base exchange complex. The most permanent of these sources is from the exchange complex. This is because potassium in the fertilizer band, if not taken up by the plants, will go into solution and be subjected to adsorption on the base exchange complex; and potassium in the soil solution that cannot find a place on the base exchange complex will be leached out if not readily absorbed by the plants.

The amount of adsorption of applied fertilizer potassium on the base exchange complex is inversely proportional to the firmness with which the ions being replaced are held. According to the lyotropic series, hydrogen is held more firmly than calcium. On this account the chances of potassium finding a place on the base exchange complex would be considerably enhanced if calcium and not hydrogen was the prevalent ion. Volk and Bell (18) working with seven Florida soils, found that on an average the leaching loss of applied potassium was two and a half times as much at pH 5.5, and four and a half times as much at 4.0, as it was at 6.8. Their results are shown in Figure 2. It must be remembered, however, that added calcium will crowd potassium as well as hydrogen off the base exchange and it thus may be lost to the plants.

If the advantages due to greater fertilizer potassium being adsorbed and the disadvantages due to the loss of exchangeable potassium are weighed, it is quite possible that liming would be practiced as far as potassium is concerned for most of the acid soils of Florida. Some of the reasons for this conclusion are: 1. The tremendous loss by leaching and hence the need for large amounts of supplemental potassium. 2. The acid soils of Florida have generally a low exchange capacity and initially possess only a very small percentage of the potassium needed for increased yields.

MOLYBDENUM

Very recent work at Hastings, Florida, on cauliflower indicated that molybdenum deficiency of soils could be averted either by liming or by the addition of molybdenum (3). Other workers have obtained similar results with other crops (5). Oertel et al (11), working with subterranean clover in Australia, found that liming increased the availability of molybdenum up to pH 7; and Evans and his co-workers (1), found a close relationship between pH value of soils and the molybdenum content of alfalfa grown on them. At low pH values they obtained increased yields for molybdenum but responses at high pH values were less pronounced. Evans et al (4). also found that the molybdenum content of alfalfa from naturally neutral or slightly alkaline New Jersey soils was very low and they suggested that molybdenum had been lost by leaching at the high pH values that occurred during the soil forming process.

From this it appears that at least part of the molybdenum forms some insoluble compound in acid soil which in the presence of lime becomes soluble. The possibility of leaching in highly limed soil should be considered.

Boron

Jones and Scarseth (7) were among the first to stress the importance of a proper Ca B ratio for plants They found the ratio for oats and tobacco to be 200 to 1 and 1200 to 1 respectively and if the ratio le reased boron toxicity would occur Lorenz (8) working with beets

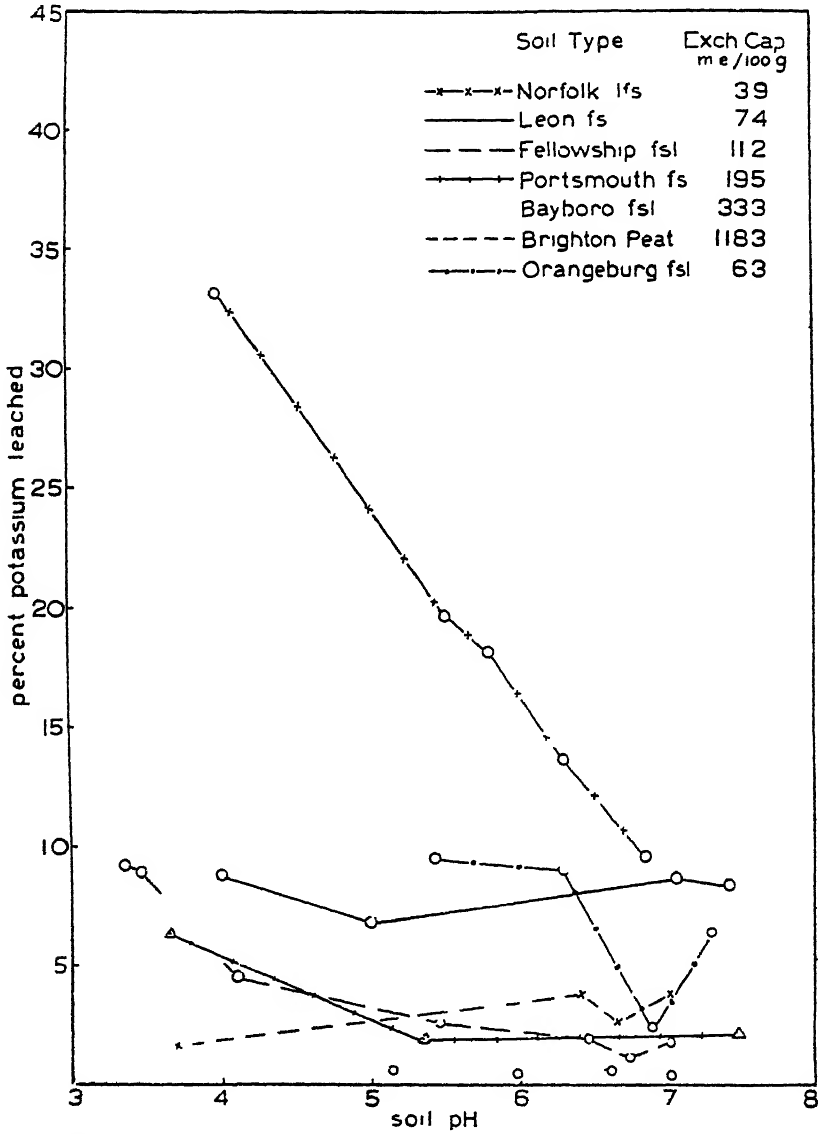

Figure 2—Effect of soil pH on the retention of potassium against leaching Treatment 9 inch soil profile in 4-gallon lysimeters treated with NH_4NO_3 and K_2SO_4 in solution at rates of 570 and 370 pounds per acre respectively and leached 36 hours to deliver 21 inches of leachate Volk and Bell (18)

found that additions of calcium to boron toxic soils would alleviate boron toxicity and he suggested that this was due to the restoration of the proper Ca B ratio. Purvis and Hanna (13) were able to restore normal growth to boron deficient plants on over limed soils by adding a source of available boron.

TABLE 1.—Influence of Long Established Reaction Levels in Lakeland Fine Sand upon the Level of Native and Applied Water Soluble Boron (as ppm B) in Air Dried Soil

Soil Treatment	pH Levels					
	5.27	5.20	5.44	6.39	6.63	7.01
Native soil boron after 20 years (ppm boron)	0.08	0.06	0.09	0.10	0.10	0.16
4 months after 200 lbs borax per acre (ppm boron)	0.27	0.28	0.69	0.61	0.66	0.95
12 months after 200 lbs borax per acre (ppm boron)	0.20	0.17	0.17	0.19	0.22	0.36

* Tests made on 0.6 inch depth.
* 5.27 and 5.20 obtained by adding sulfur, 5.44 was normal pH and the soils having pH levels of 6.39, 6.63 and 7.01 received lime.

Winsor (20, 21) working on Florida soils, found that the retention of native and applied boron was greater at the higher pH levels (Table 1) but that the maximum plant uptake was at about pH 5.8 to 6.0 (see Table 2 for effect upon collards). Winsor stated that the retention of soil boron by excessively high reaction levels was at the expense of plant assimilation. Brioux and Jones (2) attribute the conversion of boron to the unavailable state in the over limed soils to the formation of insoluble calcium borate, while Bobko et al. (1) suggest that over liming stimulates microbiological activity which depletes the soil solution of available boron. These theories, however, have not been widely accepted.

TABLE 2.—Influence of Reaction Levels in Lakeland Fine Sand upon Boron Uptake by Collards as Determined by Extraction from Foliage and by Ashing

(As micrograms of boron from 5 sq. cm. of foliage)

Pounds per Acre		Soil pH	Foliage Boron	
Borax	Reaction Supplement		By Extraction	By Ashing
10	Sulfur 500	4.31	0.31	0.84
10	None	5.14	0.41	0.92
10	Lime 500	5.78	0.12	0.96
10	Lime 1500	5.99	0.51	1.16
10	Lime 4500	6.66	0.36	0.99

Zinc, Copper and Manganese

Zinc, copper and manganese are affected by pH in much the same way as boron in that raising the pH decreases their availability.

Peech (12) added copper and zinc at the rate of 100 pounds per acre to samples of Lakeland (Norfolk) fine sand, and after adjusting the pH with sulfur and lime, brought them to 50% moisture content, left them 48 hours and extracted the available copper and zinc. His results, shown in Figure 3, indicate that the extractable copper and zinc decrease rapidly with an increase in pH and this decrease is much greater with copper.

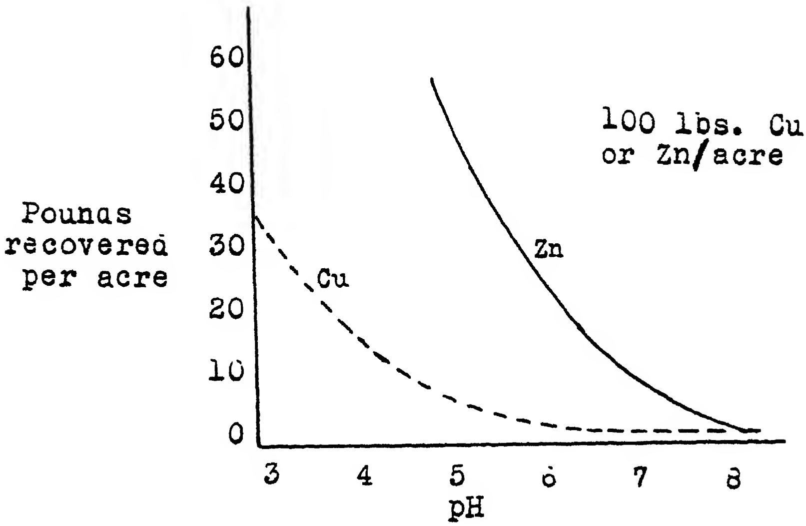

Figure 3.—Effect of pH on recovery of Zn and Cu from Lakeland (Norfolk) fine sand. Peech (12).

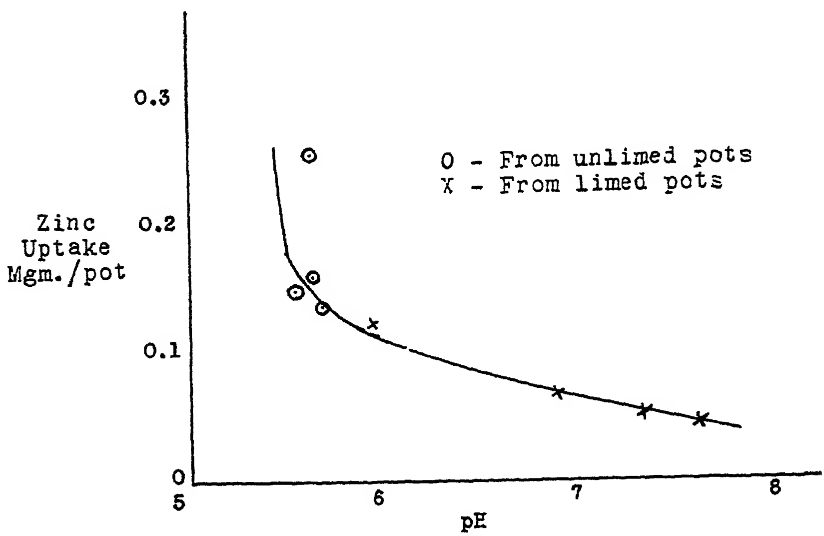

Figure 4.—Effect of pH on uptake of zinc by Camellia oats grown on Lakeland (Norfolk) fine sand. Wu (22).

Steckel (16) growing soybeans found that manganese deficient soils had a pH of 6.5 or greater. Wu (22) found that the uptake of zinc by oats was much less at higher pH values. Her results are shown in Figure 4.

It also has been found that liming soils of low pH value will counteract toxicity of these elements. This seems logical since liming would cause the quantity in excess to become unavailable. Similarly, liming border line soils would probably cause deficiencies.

For better preservation of copper, zinc and manganese in acid soils moderate liming is beneficial. Leaching becomes less at the expense of availability and it is a matter of weighing these two factors under Florida conditions. If just enough lime is added the decrease in availability might not be serious since the quantities of these elements required by plants are small; but if no lime is added to some of the more acid soils the losses due to leaching could result in severe deficiencies.

CONCLUSION

Some of the effects of lime on the availability of nutrient elements have been reviewed for nitrogen, phosphorus, potassium, molybdenum, boron, zinc, copper and manganese.

It can be said with certain reservations which include disease control and special crops, that Florida soils below pH 5.5 should be limed if more efficient utilization of applied fertilizer is desired. Similarly, under Florida conditions pH values above 6.5 should be avoided because of the reduced availability of many of the minor elements, for example, manganese, zinc, copper and boron. pH values above 6.5 have frequently resulted in deficiency of these elements and is known as overliming injury.

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THE USE OF LIMING MATERIALS ON ROW CROPS AND PASTURES

W. G. Blue *

There are essentially three reasons for applying liming materials to Florida soils. They are: (a) to change the soil reaction (pH), (b) to supply the essential plant nutrients calcium and magnesium, and (c) to reduce the loss of nutrients by leaching. These are not necessarily listed in order of importance since this is not always the same but depends on the combination of soil and crop in question.

The soil acidity tolerance of plants used for row crops and pastures is quite variable but most of them grow better at a pH range above 5.5. Most legumes are particularly sensitive although there is some question as to whether their lack of tolerance for acidity is due to the short supply of calcium associated with acid soils or to injury to their symbiotic bacteria. Since many Florida soils are too acid for optimum growth of most economic plants, liming materials must be used to reduce their acidity. The amount of lime which should be applied to obtain the desired change in soil reaction is not a constant factor but is dependent on the base exchange capacity and the degree of saturation of the soil colloids with bases. Table 1 shows the amounts of high grade calcic limestone necessary to raise the pH approximately 1.0 unit for soil areas with different exchange capacities resulting primarily from different organic matter levels (19).

TABLE 1.—The Maximum Amount of Ground Limestone Which Should Be Applied at One Time to Obtain 1.0 Unit Change in pH. Volk (19).

Soil Group	Pounds per Acre of Agricultural Limestone to Raise pH 1.0 Unit
Scrub land sands and white sands in general	500
High pine land fine sands and light gray flatwoods sands	1000
High pine land loamy fine sands and medium gray flatwoods sands	1500
High pine land sandy loams and dark gray flatwoods sands and sandy loams	2000
Clay loams, clays and black mineral soils, depending upon texture and humus content	2000-6000
Peats and mucks	6000

Most of the soils used for production of row crops and pastures in Florida are sandy and slightly to strongly acid. These conditions are

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indicative of soils in which leaching is very active and the result is a deficiency of the essential basic elements calcium, magnesium and potassium. It is generally necessary when improving these soils to apply liming materials to prevent possible deficiencies of calcium and magnesium.

Volk and Bell (18) have shown that potassium, ammonia nitrogen, magnesium and calcium leach less severely from slightly acid soils than from highly acid soils. Neller et al. (14) have shown that larger percentages of applied phosphorus are retained by sandy soils when the acidity is reduced by liming. On the other hand, most of the essential minor elements become more insoluble and unavailable for plant use at soil reactions maintained near neutrality as compared to more acid conditions, particularly on the lighter sandy soils. Peech stated that the soil reaction should not be increased above pH 6.0 in order to avoid minor element deficiencies (15).

ROW CROPS

Experimental work with corn and cotton in North and West Florida has not shown consistent response from the application of either high calcic lime or dolomite. Small yield increases have been reported for corn and cotton in some instances at the North Florida Station (20, 21, 22). Investigations in other parts of the country have shown that lime applied to soils with pH values similar to those of North and West Florida has benefited these two crops. This response has been attributed primarily to the increased availability of essential elements other than calcium and magnesium and to the change in soil reaction to favor increased microbial activity. The accelerated decomposition of the large reserves of organic matter and the accompanying decomposition of primary minerals in the soil released both nitrogen and the inorganic elements, which in some cases resulted in phenomenal yield increases. The practice of using lime alone practically devastated the soils of some areas of the East and Midwest before it was realized that other soil amendments and good management practices in addition to lime are necessary to maintain soil fertility.

Lime has been indirectly beneficial to non-leguminous row crops through its favorable action on the preceding green manure crops. Sweet clover which is used in many areas as the major green manure crop responds well to lime on most soils, but lupine, which is the predominant green manure crop in Florida, does not respond consistently to applications of lime even on soils which are quite acid. The reason for this is not fully understood. However, the tolerance for acidity of the symbiotic bacteria associated with lupine is greater than that of most legumes (9). It has also been reported that lime may not only fail to benefit lupine but may be injurious (6). Lupine is highly beneficial as a green manure crop in row crop production but because of its peculiar nature, lime does not usually enhance its value.

The requirement for calcium and magnesium by non-leguminous crops is usually less than that for most legumes and it is possible that sufficient amounts of these elements are supplied in the low analysis mixed fertilizers used in their fertilization. Superphosphate contains about 20 percent calcium and in addition many companies use dolomite as the filler

for fertilizers which are to be used on acid soils. "Floats," a product of the phosphate industry, is another material used which contains calcium.

The selection of new experimental areas each year has been one shortcoming of research involving lime applications on Florida soils used for growing these crops. Yields have also been low, and in many cases droughty conditions, thin stand of the crop or a greater deficiency of the other major plant nutrients have probably precluded yield responses from liming materials. At present, soil management experiments involving the use of liberal quantities of nitrogen, phosphorus and potassium with green manure crops and the use of proper cultivation practices have resulted in as much as threefold increases in yields of corn. The increased demand for calcium and magnesium brought about by larger yields should better establish the extent of need for liming materials on these soils.

The nutrition of peanuts presents a more complex problem than that of most row crops. The need for calcium and magnesium by this leguminous plant is rather high, yet Killinger et al. (12) reported that peanut yields in Central and North Florida were not increased by the use of either high calcic limestone or dolomite. Davis (7) reported that for soils in southeastern Alabama lime increased the yields of peanuts if the soils contained less than 0.72 m.e. of calcium. The number of mature kernels was also increased. Other workers (5, 13) have reported results similar to these and have indicated that the exchange capacity must have a high degree of saturation with calcium for best yields.

PASTURES

The improvement of pastures in Florida has been of relatively recent occurrence and it has been possible to profit by earlier work in other areas. Since the lack of water may limit yields of pastures the initial tendency has been to establish improved pastures on areas having good moisture relationships. This condition is favorable for excellent response to lime and other soil amendments. Both the heavier soils of west Florida and the sandy flatwoods soils of peninsular Florida are being used extensively for improved pastures. The fertility of the soil of both these areas in the virgin state was relatively low. The pH of the soils in the flatwoods areas is in general lower than that of the soils in west Florida. The range in pH for virgin flatwoods soils is about 4.0 to 5.0 while the pH values for soils in north central and west Florida ranges from about pH 5.0 to 6.0.

Contrary to the results obtained with the row crops, pasture plants, both leguminous and non-leguminous, have responded favorably to either high calcic limestone or dolomite in Florida. This is also true for most areas of the United States outside of the alkali areas of the west and southwest.

Blaser, in 1938 (1), showed that adapted strains of clover could be successfully grown when adequate quantities of lime and fertilizer were applied to the soil. Ground high calcic limestone at rates of 2000 to 4000 pounds per acre gave good results, and good clover growth was obtained with soil acidity varying from pH 4.9 to 6.0 and above. Both high calcic limestone and dolomite gave good results. In other work Blaser et al. (2) used a treatment of 2000 pounds of high calcic limestone, 600 pounds of superphosphate and 100 pounds of muriate of potash

per acre for mixed plantings of California bur and White clover on Leon fine sand pH 4.9 and Plummer fine sand pH 5.3. The substitution of dolomite for the high calcic limestone resulted in significantly lower yields on Leon fine sand, while yields were about equal on the Plummer fine sand. Yields on both soils were lower where the amount of lime used was decreased. There was also a differential growth of the two clovers. California bur, a Medicago species, made up a progressively smaller percentage of the number of plants as the lime was reduced. Also a reduction in the amount of high calcic lime applied, or the substitution of dolomite, decreased the calcium content of both clovers. The Trifolium clovers were well nodulated in all cases but the number of nodules was reduced as the amount of lime was reduced. The number of nodules on the Medicago-Melilotus clovers was less than on the Trifolium clovers with the standard treatment and nodulation was practically eliminated where no lime was added.

The need for selective liming of different clover combinations was previously emphasized by Stokes et al. (17). On an acid flatwoods soil the Medicago and Melilotus clovers gave greater response with high calcic limestone than with dolomite, while the Trifolium clovers responded equally well to either lime source. It is known that the former two genera of clovers favor higher pH values than the latter, either because of a high calcium requirement or the effect of the calcium on soil acidity and their symbiotic nitrogen fixing bacteria. Since the rate of solubility of dolomite with the same fineness of grinding is only about 50 percent as rapid as for high calcic limestone, the soil reaction would change more quickly with high calcic limestone and greater response would be obtained with the Medicago and Melilotus clovers from it than from dolomite, particularly the first year. Hodges (11), at the Florida Range Cattle Station, reported that most flatwoods soils require about two tons of lime per acre for clovers and that either high calcic lime or dolomite may be used.

Gammon et al. (10) in recent work at the West Florida Station on Carnegie and Tifton fine sandy loams have demonstrated clearly the need for lime on the heavier soils of West Florida. These data are shown in Table 2. The indicator pasture plants were White clover and Dallis grass. Dolomite was used because it was readily available in that area, but there was no readily apparent advantage or disadvantage from its use over high calcic limestone. One-ton per acre of ground high grade dolomite gave the largest yield increase per unit applied. Small yield increases resulted from rates of dolomite up to four tons per acre. Since the amounts of other nutrients added are now known to be only moderately high it was suggested that a two-ton rate might be more desirable.

The response of clovers to liming materials is probably due both to the increased calcium supply and to the increase pH of the soil. The symbiotic nitrogen fixing organisms associated with most of the clovers do not function efficiently at pH values much below 5.0. The optimum pH for some of them is above 6.0.

In 1938 it was reported that response with pasture grasses was obtained with mixed fertilizer on limed plots but not on unlimed plots (16). The pH of the soils varied from 5.64 to 6.02 on unlimed plots and from 5.89 to 6.32 on the limed plots. Six hundred pounds of $Ca(OH)_2$ per acre was used as the liming material. The favorable effect of the lime

could have been the result of either the correction of a calcium deficiency or a greater retention of other essential nutrients rather than to the reduction of acidity as such. Blaser and Stokes (3) reported that the omission of lime from a fertility program for pure stands of carpet grass resulted in retarded growth and plants with a lower calcium content. Yield responses from grasses seem to result to some extent from the calcium applied and certainly the calcium content of the forage plants is increased. However, much greater response results indirectly through the stimulation of clover growth and nitrogen fixation and the subsequent release of this nitrogen and inorganic elements for utilization by the grass plants after the clover has become dormant. Thus, in cases of grass-legume combinations which are being recommended for all areas with suitable moisture relationships, responses from liming materials are very high for both groups of plants (4, 10).

TABLE 2.—EFFECT OF LIME ON FIRST-YEAR YIELDS OF LOUISIANA WHITE CLOVER-DALLIS GRASS PASTURE PLOTS AT WEST FLORIDA EXPERIMENT STATION. GAMMON (10).

Dolomite Lbs./Acre	Soil pH	Fertilizer Lbs./Acre	Fertilizer Formula	Yields Air-Dry Herbage in Lbs. per Acre 4-1-49	5-16-49	8-11-49	10-10-49	Total
0	5.33	600	0-15-10	93	272	1523	128	2316
2000	5.88	600	0-15-10	423	750	2232	598	4003
4000	6.23	600	0-15-10	456	925	2685	676	4742
8000	6.51	600	0-15-10	410	951	2900	698	4959

Yields first year after application of dolomite.
Yields from first two cuttings represent white clover, and from last two Dallis grass.

Where ammonium forms of nitrogen are used for grass fertilization on highly acid soils, response from lime is also obtained through the decrease in soil acidity which creates more favorable conditions for growth and activity of the nitrifying organisms and results in a greater supply of nitrate nitrogen for grass nutrition. This is particularly true on some of the flatwoods soils such as the Leon fine sand which frequently has pH values below 4.5.

Experimental evidence has not shown dolomite to be of any value over calcic limestone for pastures. However, liming materials of some type must be used for satisfactory yields from pasture areas along with additions of the major elements and in some cases the minor elements. Dolomite usually gives results nearly comparable with high calcic limestone, and principles of soils and plant nutrition would indicate that fully as good results would be obtained if the dolomite were applied sufficiently in advance of seeding to allow for some decomposition. Dolomite has not increased forage yields over high calcic lime but the magnesium content of the forage is increased. The lack of yield response is somewhat confusing since most Florida soils are relatively low in magnesium. Forbes (8) reported that the bulk of magnesium in the flatwoods soils is present in the soil organic matter. The most reasonable explanation for lack of response is that areas chosen for pasture improvement are

comparatively high in organic matter and this supply of magnesium is supplemented with magnesium added in the high calcic agricultural limestone or in the filler material of mixed fertilizers.

The problem of maintaining soil fertility becomes increasingly difficult when vegetative material is removed from the soil by clipping or by intensive grazing. As more is learned about methods of curing hay under Florida conditions, greater quantities of forages may be removed from the soil to meet the demand for supplemental feed. Accompanying this will be a greater removal of plant nutrients, and it is likely that this factor, combined with continued use of the land, will create a need for dolomite and possibly minor elements.

SUMMARY

The field crops grown principally in north and west Florida do not respond consistently to either high calcic limestone or dolomite.

Pasture plants, both legumes and non-legumes, respond well to either high calcic limestone or dolomite on most mineral soils in the state but from the standpoint of yield increases there seems to be no benefit from dolomite over high calcic limestone. Pasture grasses planted in pure stands usually respond much less to lime than do pure stands of legumes. but in mixed plantings the grasses respond very favorably because of larger quantities of nitrogen fixed by the legumes and the release of some of this nitrogen for utilization by the grass when the legumes become dormant or die.

Even though some crops do not show a direct yield response to lime applications it is generally recommended for mineral soils that the entire farm area be limed to give a pH of about 5.5 to 6.0. This soil reaction will favor pasture plants and should improve row crops since more nitrogen will generally be fixed by legumes which respond to lime. The active organic matter will also be maintained at a higher level and the amounts of essential nutrients lost by leaching will be appreciably reduced.

While liming materials are extremely beneficial if properly utilized. there is some danger of overliming sandy soils of low buffer capacity if caution is not observed. Overliming can make minor elements unavailable and the productivity of the soil may be seriously impaired. It should be remembered that it is much easier to increase the pH to the proper level than to reduce it, in case it is too high.

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THE LIME REQUIREMENTS OF VEGETABLE CROPS ON THE SANDY SOILS OF THE LOWER EAST COAST OF FLORIDA

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The discussion of lime requirements of any crop on the sandy soils of the Florida lower east coast involves a consideration of pH and calcium and magnesium needs. Methods of pH determination have been reviewed in some detail by Carrigan (2) and Volk (5). The effect of pH on the availability of ions in light sandy soils has been investigated and reported by Peech (4). The significance of pH as it relates to lime requirement, movement of surface applications of liming materials, base saturation, retention of potassium and ammonia, and solubility of phosphates also has been investigated and reported by Volk (5).

Liming experiments with vegetable crops have been conducted by the authors on the sandy soils of St. Lucie, Martin and Palm Beach Counties. Results of one experiment have been reported (3). This discussion is a review of the work that has been done to date by investigators at the Everglades Experiment Station on sources and application rates of liming materials used with vegetable crops on the mineral soils of the lower east coast of Florida.

The results of the liming phases of an experiment conducted during the spring of 1947 on Immokalee fine sand in St. Lucie County with tomatoes are recorded in Table 1. This soil had not been limed and the average analyses with respect to pH, Ca and Mg are represented by those reported for the check treatment, Table 1. The basic slag, dolomite and hydrated lime were broadcast at the rates of 2000, 2000 and 1000 pounds per acre, respectively, about three months prior to collection of the soil samples and about five months prior to collection of the tissue samples, the average analyses of which are recorded in Table 1. The analyses of both soil and tissue samples correlate very closely with each other and the various treatments. The total yields of tomatoes were increased significantly by all of the liming treatments. Random samples of mature green tomatoes which appeared to be externally sound were collected during the third picking. Six fruit from each plot were cut in half, examined and scored for a condition that may be described as an internal browning and hardening of small areas within the outer and radial walls of the fruit having the appearance of granules of brown, cork-like material. These scores, also recorded in Table 1, indicate that liming had a significant effect on the reduction of this condition. Although not statistically significant it may be of some practical significance that basic slag, of all the liming materials used, gave the highest yields and lowest incidence of internal necrotic tissue.

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TABLE 1. RELATION OF LIMING TREATMENT TO SOIL AND TISSUE ANALYSES AND TO YIELD AND QUALITY OF TOMATOES ON IMMAKALEE FINE SAND IN ST. LUCIE COUNTY.*

Treatment §	Soil Analyses*			Tissue Analyses† Oven-Dry Basis (%)		Tomatoes	
	pH	Ca Lbs/A	Mg Lbs/A	Ca	Mg	Total Yield, Field Crates/A	Score for Internal Necrotic Tissue ‡
Check	4.75	169	10	0.59	0.33	151	43
Basic Slag	6.13	495	35	0.75	0.42	273	10
Hydrated Lime	6.56	497	18	0.73	0.44	263	15
Dolomite	6.31	413	113	0.64	0.57	235	20
L.S.D. (19:1)				0.11	0.06	48	23

* Average of four plots.

* Glass electrode method for pH, 0.5 N acetic acid soluble Ca and Mg.

† Filtrates from extraction of fresh stem tissue in a Waring Blendor with 0.5 N acetic acid.

‡ Internal browning condition of six externally sound mature green fruit from each plot scored on the basis of none = 0, slight = 1, medium = 2 and severe = 3.

§ Basic slag and dolomite applied at rate of 2000 pounds and hydrated lime at 1000 pounds per acre.

A similar type experiment was conducted with tomatoes and squash on a Sunniland fine sand in Martin County during the 1947-48 season. The results of that portion of the experiment dealing with the effect of liming materials on tomatoes are recorded in Table 2. The dolomite and slag were broadcast at rates of 1000 pounds per acre in September and again in February prior to collection of soil samples in March and tissue samples in May. Here again good correlation was obtained between soil tests, tissue tests and treatments. Tomatoes showed a significant yield response to basic slag treatments. Since the soil reaction before liming was quite satisfactory, pH 5.76, it is not at all surprising that the yield responses were small. After the first two pickings it was noted that fruit from some of the treatments had a tendency to become soft after harvesting and to break down severely during shipping. In order to check the relationship of this characteristic to treatment, one box of fruit was saved from each plot during the fourth picking. After washing and sorting in the field each lot of fruit was run over the belt at a packing house and waxed. The boxed fruit samples were placed in a refrigerator car for six days, removed and allowed to stand at room temperature for three more days. Ten days after picking the tomatoes were then examined for spoilage and internal quality. There were no differences in spoilage with respect to treatment as determined by an examination of external condition. Twenty-five ripe and externally sound fruit from each plot were cut in half and examined for internal breakdown consisting of soft, light-colored or yellow spots in the walls between or around the seed sections. Many of the fruit showing such symptoms had a strong odor and taste of over-ripe tomatoes. The results of this examination with respect to liming treatment are recorded in Table 2. Highly significant differences were obtained. Fruit from the basic slag plots was statistically more sound than that from any other treatment.

However. the dolomite treatment produced fruit statistically more sound than the check treatment.

TABLE 2.—RELATION OF LIMING TREATMENTS TO SOIL AND TISSUE ANALYSES AND TO YIELDS AND QUALITY OF TOMATOES ON SUNNILAND FINE SAND IN MARTIN COUNTY

Treatment §	Soil Analyses			Tissue Analyses† Oven-Dry Basis (%)		Tomatoes	
	pH	Ca Lbs/A	Mg Lbs/A	Ca	Mg	Total Yield, Field Crates/A	Internal ‡ Soften-ing (%)
Check	5.76	360	23	0.81	0.29	550	16
Dolomite	6.67	638	95	0 92	0.44	588	34
Basic Slag	7.04	721	41	1.00	0.31	627	23
L.S.D. (19:1)						45	11

* Average of five plots.

Glass electrode method for pH. 0.5 N acetic acid soluble Ca and Mg.

† Filtrates from extraction of fresh stem tissue in a Waring Blendor with 0.5 N acetic acid.

‡ Percent of externally sound fruit showing some form of internal breakdown after ripening. Estimates made by J. C. Hoffman, Associate Horticulturist, Everglades Experiment Station, Belle Glade, Florida.

§ Dolomite and slag applied broadcast at 2000 pounds per acre in two equal applications.

A second crop of tomatoes was grown on the Martin County plots during the fall of 1948. Bacterial wilt depleted the stand to such an extent that there was no way to measure yield variations with respect to treatment. A random sample of 50 tomatoes was collected from each plot at the time of the fourth harvest. Average weight per fruit was larger and the fruit were firmer from the limed plots than from the unlimed plots but the differences were not statistically significant. Two other experiments with tomatoes on Immokalee fine sand in eastern Palm Beach County failed to show any significant differences with respect to yields and quality among eight different liming treatments.

In both experiments represented by the data in Tables 1 and 2 some foliage symptoms of magnesium deficiency were noted on part of the check plots. The symptoms were more severe on the plots represented by Table 1. A careful study of the soil and stem tissue analysis data in Tables 1 and 2 indicates that no magnesium deficiency was diagnosed where the soil test for Mg was 35 pounds per acre or above and where the stem tissue showed 0.31 percent or more of this element. In order to insure, with some margin of safety, absence of magnesium deficiency on tomatoes these data indicate that the soil should test above 40 pounds per acre and the extracted fresh stem tissue about 0.40 percent or higher on the oven-dry basis.

Soil heterogeneity caused by small patches of marl and soft limerock near the surface in some plots on the experimental area in Martin County classified as Sunniland fine sand afforded an opportunity to study the response of tomatoes and yellow crookneck squash to soil pH, whether caused by naturally occurring lime or applied lime from any source. A scatter diagram of squash yields is shown in Figure 1 and of tomatoes

FIGURE 1,—SCATTER DIAGRAM OF SQUASH YIELDS WITH SOIL pH ⊛

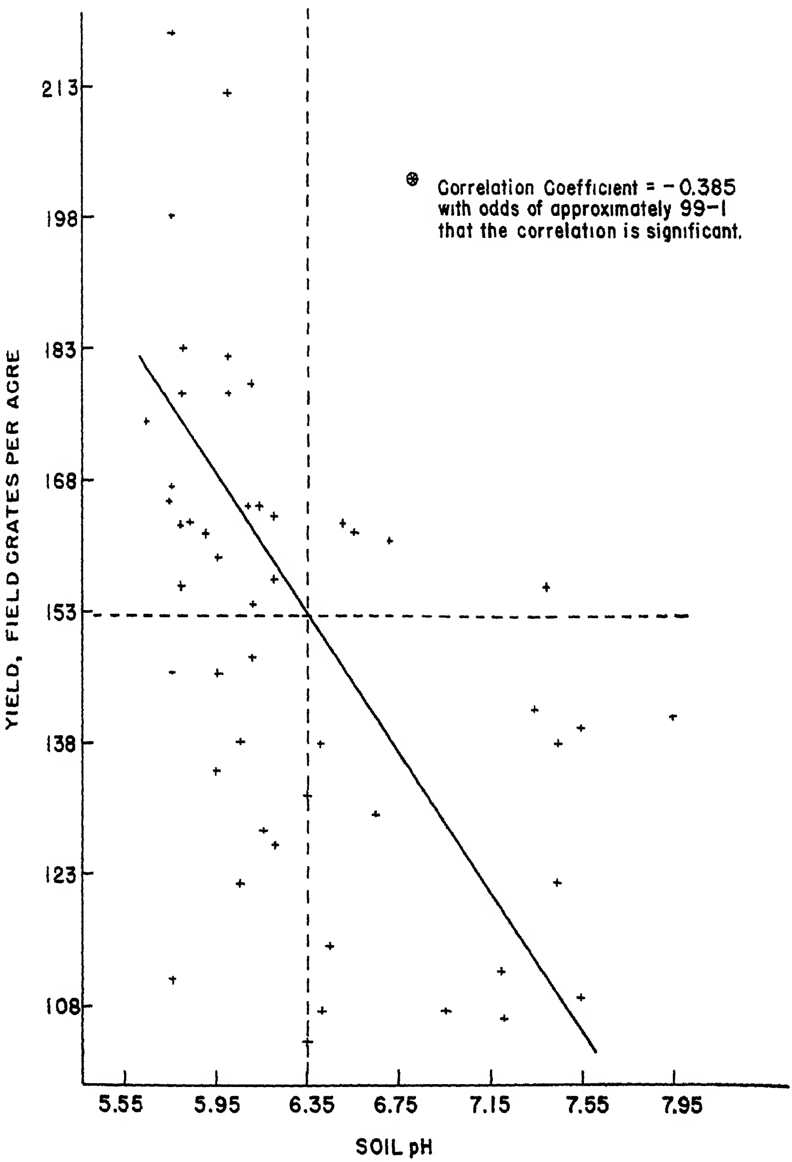
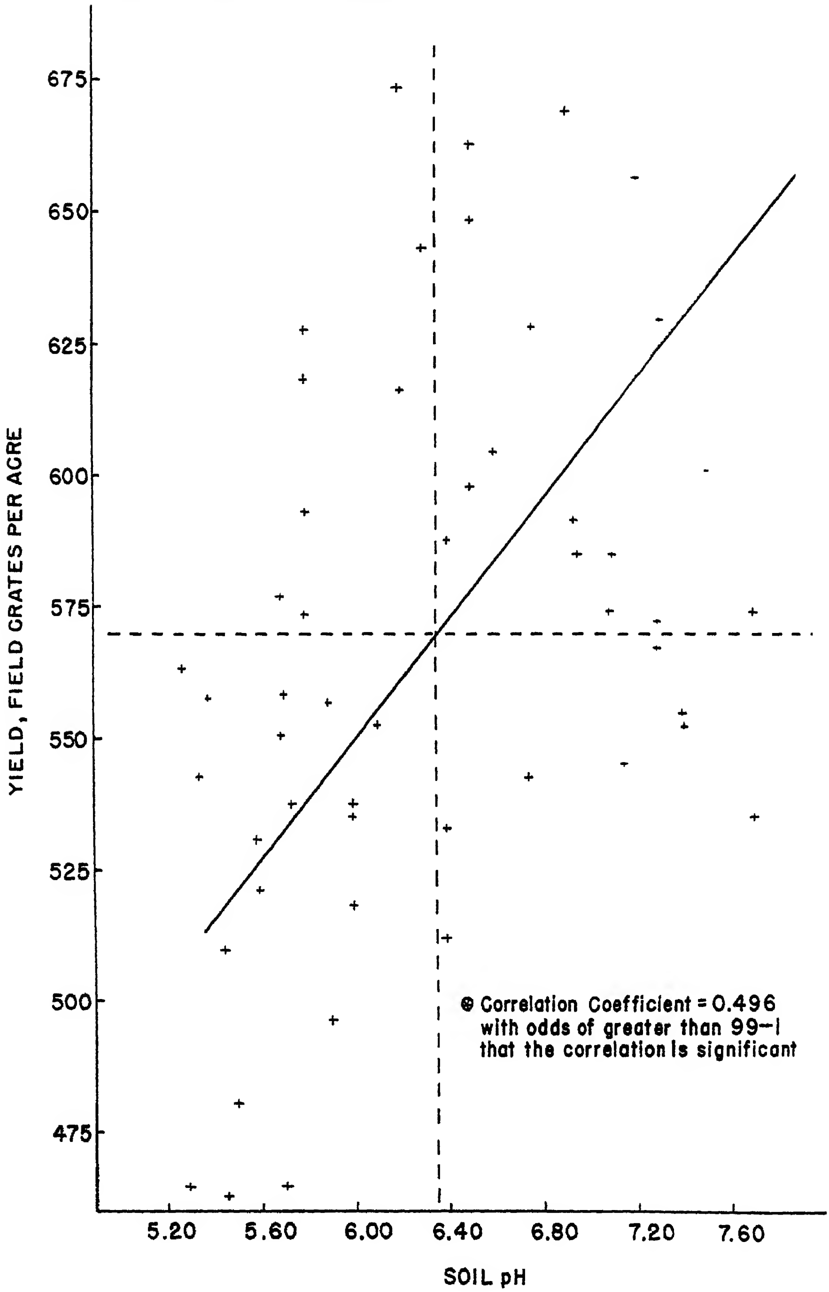


FIGURE 2.- SCATTER DIAGRAM OF TOMATO YIELDS WITH SOIL pH ⊗



in Figure 2. The yield trend for squash was downward as the pH increased from 5.60 to 7.90 while the yield trend for tomatoes was upward as the pH increased from 5.30 to 7.60. Although not conclusive, the data indicate trends that should be considered when contemplating a liming program for either of these crops. In contrast to these data Beckenbach (1) in 1946 obtained reduced yields of tomatoes with high lime treatments on Bradenton fine sandy loam while in 1948 there was no yield response in the same crop with pH increases from 4.8 to 6.8.

Treatments consisting of several lime sources and gypsum applied at rates of 2000 pounds per acre were made to a set of plots established in 1949 on Immokalee fine sand in eastern Palm Beach County. These plots were planted to several different vegetable crops during a three year period. Some of the data are recorded in Table 3. Although soil samples were collected during each crop, only the average analyses for those obtained during the spring of 1950 are recorded in the Table. The effects of the liming treatments on the soil pH, and on the Ca and Mg contents are obvious and somewhat according to expectations. The large amount of magnesium in dolomite and the somewhat smaller amounts in the slags are reflected in the results of the soil tests. Although 2 percent MgO had been included in the fertilizer for the gypsum treatments for almost two year's of cropping, it did not show in the test. Evidently the unused amounts had been lost through leaching. Most of the calcium in the gypsum was not removed by the 0.5 *N* acetic acid used in the soil tests to extract the bases. Some of the average vegetable yields for 1949, 1950 and 1951 are recorded in Table 3. The only crops that showed statistically significant yield increases to applications of any of the lime sources were snap beans and sweet potatoes. Beckenbach (1) reported higher bean yields in 1944 with the use of dolomite applied at the rate of 1500 pounds per acre on Bradenton fine sandy loam. Squash, Table 3, showed a tendency to increased yields but the differences were not statistically significant. This is a reversal of the trend indicated by the scatter diagram of another experiment represented in Figure 1. However, the latter crop was grown in a pH range of 5.60 to 7.90 while the range in the experiment of Table 3 was 4.68 to 5.90. Lima beans showed a tendency toward decreased yields due to liming. Gypsum with soluble magnesia gave no yield response with any of the crops. In fact, all yields with but one exception were below the check and this exception, snap beans in 1950, was equal to the check in yield.

The danger of overliming, which is a distinct possibility on light soils when intensively cropped, is a question of considerable importance and one which may involve extensive damage to the soil especially where soluble hydrated forms are used. During the 1950-51 season a series of experiments was conducted on a Sunniland fine sand in Martin County. The area had been previously limed two times within a year with basic slag and a high calcic form to an average pH of 6.36. Dolomite, high calcic limestone, basic slag and hydrated lime were applied at rates shown in Table 4. Sweet corn and cucumbers were planted, the sweet corn as an early winter crop and the cucumbers in the spring. The average analyses of soil samples collected from the plots about six months after the liming materials were applied are recorded in Table 4. The pH

TABLE 3 Soil Analyses and Vegetable Yields from Lime Source Plots on Immokalee Fine Sand in Eastern Palm Beach County

Treatment	Soil Analyses†			Yield, 1949	Yields Lbs/Plot 1950				Yields Lbs/Plot 1951	
	pH	Ca Lbs/A	Mg Lbs/A	Tomatoes Lbs/Plot	Snap Beans*	Tomatoes	Yellow Squash	Sweet Potatoes	Snap Beans	Lima Beans
Check	4 68	579	56	97	4	139	78	80	19	86
Dolomite	5 63	571	156	113	11	118	101	111	57	106
Basic Slag Tennessee Ground Open Hearth	5 11	515	68	85	11	125	97	76	26	83
Fairfield Slag, Ground Open Hearth	5 19	619	95	112	17	134	91	96	55	87
Blast Furnace Slag Water Granulated	5 55	676	155	92	16	123	102	115	25	71
Gypsum + Sol MgO	4 78	111	53	80	51	153	72	19	15	56
Dolomite + Rock Phosphate	5 90	736	1 9	103	12	151	79	69	25	79
Dolomite without Minor Elements	5 52	554	161	77	41	118	105	99	26	80
L S D (19 1)				N S D	4	N S D	N S D	22	10	N S D
L S D (99 1)				N S D	6	N S D	N S D	29	11	N S D

Liming materials and gypsum had been applied at the rate of 2000 pounds per acre in two applications
* Average for two varieties whose yield trends were similar with respect to treatment
† Averages of analyses made on samples collected in 1950 Glass electrode method for pH 0 5 N acetic acid soluble Ca and Mg

values had not increased above 6.91 on any of the treatments. The highest pH value from dolomite applied at 1000 pounds per acre was only 6.65. This is in agreement with experiments of Beckenbach (1) who reported in 1919 a maximum pH of 6.9 which dropped after six months to 6.5 after the last of a series of seven yearly applications of 1500 pounds per acre of dolomite had been made on the Bradenton fine sandy loam. The analyses for Ca and Mg clearly show the relative amounts of these elements present in the soil after treatment. Sweet corn showed no yield differences or even trends except that there was slight tendency toward reduced yields with hydrated lime and with the highest dolomite application. Although not significant, the length of unfilled tip on the ears of sweet corn appeared to be slightly reduced by all of the liming treatments.

Just prior to the first harvest of cucumbers the general appearance as to growth, color and overall vigor of the vines was scored by a commercial cucumber grower. The average scores and yields are recorded in Table 4. Although not significant, the vine scores on general appearance tended to improve with all treatments except hydrated lime which was the same as the check. The basic slag treatment yielded higher than the check while all other yields were equal to or just slightly less than the check. It may be noted that the basic slag treatment also gave the highest appearance score. On an adjacent area cucumbers responded outstandingly to regular applications of a nutritional spray containing "Nu-M," a neutral manganese sulfate. The apparent response to basic slag may have been due to the manganese contained in this source of liming material.

Three unreplicated liming tests have been conducted on soils of the Immokalee and Sunniland series with fourteen different vegetable crops. Generally speaking, all except sweet corn showed yield increases up to a pH of approximately 5.50 to 5.70, and sweet corn showed an improvement in quality and earliness of maturity. Beyond this point the yield responses have been quite variable, some being positive and some negative. Lima beans and squash were most consistent in their yield decreases past a pH of approximately 5.50 to 5.80. Pepper, eggplant, tomatoes and snap beans usually responded to lime. Others were rather erratic in their responses. Beckenbach (1) reported in 1919 that "Bradenton series soils of pH 5.1 to 6.8 range will not respond to liming, either in returns from a cash crop or in growth of leguminous or other summer cover."

These and other experiments carried out on the sandy soils of Florida indicate that it would be best for general vegetable production to adopt a liming program that would hold the pH value within a range of 5.60 to 6.00. This pH range seems to be safe for most vegetable crops and is fairly consistent with good soil conservation practices. Somewhat higher pH values may be maintained for certain vegetable crops with some possibility of increased yields and quality. Most of the so called "insoluble" sources of lime are rapid enough in their action for general use and seem to be safe to use insofar as the dangers of over liming are concerned. Where magnesium is limiting, as it is on most of the sandy soils of the Florida lower east coast, a magnesium bearing material is recommended at least for periodic applications. Because of the outstanding results in increased yields and improved quality obtained from open hearth slags, these materials are suggested for use in a well balanced liming program.

TABLE 1. Relation of Sources and Application Rates of Certain Liming Materials to Soil Analyses and to the Production of Sweet Corn and Cucumbers on Sunniland Fine Sand in Martin County.*

Treatment **	Soil Analyses †			Sweet Corn		Cucumbers	
	pH	Ca Lbs/A	Mg Lbs/A	Yield of Marketable. Lbs/Plot	Average ‡ Length of Unfilled Tip, cm.	Score § of Vine Appearance	Total Yield Lbs/Plot
Check	6.36	870	88	31	3.2	3.9	98
Dolomite at 2000	6.59	1260	252	30	3.0	1.5	98
Dolomite at 4000	6.65	1560	368	28	2.9	4.7	92
High Calcic at 2000	6.91	1350	92	30	3.1	1.3	89
Basic Slag at 2000	6.85	1170	136	30	2.6	1.9	111
Hydrated Lime at 500	6.85	1010	86	27	2.7	3.9	95
Dolomite at 2000 + Colloidal Phos. at 4000	6.59	1190	201	31	3.2	4.2	93
L.S.D. (19:1)	0.27	210	43	N.S.D.	N.S.D.	N.S.D.	N.S.D.
L.S.D. (99:1)	0.36	323	57	N.S.D.	N.S.D.	N.S.D.	N.S.D.

* Average of five plots.
** All materials except hydrated lime applied broadcast.
† Glass electrode method for pH. Ca and Mg determined on flame photometer after extraction with 0.5 *N* acetic acid.
‡ Average of a 25 ear random sample from each plot.
§ Scored just prior to harvest by Mr. B. G. Leighton, a commercial grower, on the basis of 1 = very poor to 10 = very good.

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The authors wish to express their appreciation to the Tennessee Coal. Iron and Railroad Company for furnishing all the slags and a grant-in-aid, part of which was used to conduct the experiments; to the Seaboard Airline Railway Company on whose property some of the studies were conducted; and to Mr. B. G. Leighton of Indiantown who furnished land, equipment and labor to conduct some of the experiments. We wish also to thank County Agents L. M. Johnson, Martin County, C. D. Kime, St. Lucie County, and M. U. Mounts and John H. Causey, Palm Beach County and Mr. R. A. Carlton, Seaboard Railway Agricultural Agent, for their interest and cooperation during the conduct of this work. Finally, we particularly wish to thank Mr. T. E. Pennington, Laboratory Assistant, Everglades Experiment Station, who helped in the mixing and application of all fertilizers and supervised the collection and analyses of all soil and plant tissue samples.

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THE USE OF AGRICULTURAL LIMESTONE AND DOLOMITE IN FLORIDA CITRUS PRODUCTION

I. W. WANDER

The use of finely ground agricultural limestone or dolomite in the production of citrus is practiced by most grove owners or their caretakers. However, the reasons for the use of dolomite or lime is not always clearly understood even by those who realize the value of such materials. The limitations of their use on mineral-deficient. acid, sandy soils is often confused with their use on heavier, mineral-rich soils. The philosophy that if some is good. more ought to be better, with respect to the use of lime. backfired on many grove owners. Such misunderstanding has resulted in severe damage in the past and. indirectly, by association, is resulting in losses of production at present.

The bad effects from overliming citrus in Florida are well known and the minor element dificiencies resulting have been described and seen by many. Although the dangers of overliming should in no way be minimized, it is believed that many growers have thus been influenced to use little or no limestone or dolomite in their regular program. This attitude coupled with the practice of using straight nitrogen sources plus high analysis mixtures containing no dolomite filler is resulting in many groves becoming too acid for efficient production.

For this reason it is believed desirable to point out the advantages of using adequate amounts of basic materials when producing citrus on the acid, sandy soils of Florida. The use of the term lime or basic materials in this discussion refers to the use of either finely ground high calcium limestone or dolomite. For practical purposes it is felt that the two materials can be used interchangeably on equal basis for the maintenance of soil reaction. It is understood that at low soil pH values, some magnesium will become available from dolomite. However, when the soil reaction is maintained at from 5.5 to 6.0, relatively little magnesium is available to citrus from dolomite.

One of the best illustrations of the advantages of soil pH control under field conditions can be found in a block of mature grapefruit trees located at the Citrus Experiment Station. Duplicate plots (four in all) of 24 trees each have been maintained since November 1938 with the same fertilizer program, differing only with respect to soil reaction. Four varieties. Marsh, Duncan, Excelsior, and Walters, are present in each treatment and each treatment receives at present a total of 75 pounds of a 4-6-8-4-1-1 mixture per tree during the year. The fertilizer applications are split into three equal parts of 25 pounds each in the spring, summer and fall. Two of the four plots receive finely ground limestone in sufficient amount to keep the soil reaction between 5.5 and 6.0 pH, while two other plots receive no supplemental lime and thus show a reaction of from 4.0 to 4.5 pH.

Soil samples were taken once each month during the period from September 1949 to September 1950 and analyses made for pH, extractable

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[1] Citrus Experiment Station. Lake Alfred.

calcium, magnesium, potassium, phosphorus, and manganese. Extractable refers to that portion of calcium (or other nutrient) dissolved from a definite weight of soil in a definite volume of extracting solution, in this case sodium acetate buffered at pH 4.8. Soil reaction determinations (pH) were made with a glass electrode on a 1 to 1 ratio of soil to water mixture of previously air dried soil.

The average pH and pounds per acre of extractable calcium, magnesium, potassium, phosphorus and manganese in the soil from controlled and uncontrolled plots during the period from September 1949 to and including September 1950 are given in Table 1. These results indicate the degree of difference in soil analysis which may be expected during a complete growing season. Although considerable fluctuations occur due to effects of fertilizer applications and rainfall, this average represents the level of nutrition which can be maintained over a period of time.

TABLE 1.—pH AND POUNDS PER ACRE EXTRACTABLE CA, MG, K, P, MN.

Treatment	Average of 13 Soil Samples Taken at Monthly Intervals—9/20/49 - 9/21/50					
	pH[a]	Ca	Mg[b]	K	P	Mn
Controlled .	5.6	1123	28.3	61.7	61.7	23.5
Uncontrolled	4.3	231	22.1	57.7	41.4	10.7
Controlled plots have	19 times less acid	386% more Ca	28.0% more Mg	12.1% more K	56.3% more P	136% more Mn

[a] Arithmetical average.

[b] It should be noted that these analyses represent results obtained from soil where the pH has been controlled by using high calcium limestone. Although the availability of magnesium to citrus would be no greater, much higher magnesium values would be found where dolomite has been used. This is due to the solubility in the extracting solution of magnesium carbonate which has accumulated in soils from dolomite applications.

The soil reaction in the plots receiving no lime shows the presence of 19 times as much active acidity compared to the plots receiving lime. This is greater acidity than is found in virgin soils of the same type. Such a result is to be expected in view of the use of sulfur sprays and dusts and the acid forming residues from sulfate forms of fertilizer source materials. It is not often realized how much lime is required to react with sulfur. To completely react one pound of sulfur requires a little over three pounds of lime. Thus the potential acidity added in the regular spray and dust program, where between 200 to 300 pounds of sulfur per acre per year is used, would require 600 to 900 pounds of calcium carbonate per acre per year or its equivalent.

The amount of extractable calcium is 386 percent greater in the limed plots compared to the unlimed areas. Triple superphosphate is used in the limed plots whereas ordinary 20 percent superphosphate containing 50 percent calcium sulfate is used on the unlimed plots in order to make the addition of calcium more nearly equal to each plot. Evidently the addition of calcium sulfate on the unlimed plots is readily lost by leach-

ing. It is also evident that it is necessary to maintain a pH higher than 4.5 to accumulate calcium.

The quantity of extractable magnesium was found to be 28.0 percent greater in the plots receiving limestone over the period studied although the amount of soluble magnesium received by all plots was the same. Analysis of variance showed this increase to be significant. The extractable potassium was 12.1 percent greater which is not great enough to be significant but appears to be in favor of the pH controlled plots. The increases of both extractable manganese and phosphorus are highly significant being 136 and 56.3 percent respectively for the controlled plots as compared to the unlimed plots.

TABLE 2.—TOTAL POUNDS PER ACRE CA, MN, CU, AND ZN.

Treatment	Average of 12 Samples Taken from 8/26/48 to 8/15/49				
	Ca	P	Mn	Cu	Zn
Controlled	1340	507	228	166	59
Uncontrolled	246	344	30	141	4.8
Controlled plots have	445% more Ca	47.5% more P	660% more Mn	17.7% more Cu	1135% more Zn

A similar pattern is revealed when analyses are made for total calcium, phosphorus and manganese in these plots. The total amounts of calcium, phosphorus, manganese, copper and zinc in the soil during the period August 1948 to August 1949 is shown in Table 2. Analyses for total copper and zinc also show significantly greater amounts present in the pH controlled plots. It is interesting to note that much less difference is found in copper concentration between the two treatments than for any other element studied except extractable potassium. Evidently copper is closely related to the organic matter present in the treatments because the organic matter content of all plots is nearly equal.

TABLE 3.—YIELD IN POUNDS PER TREE.

Treatment		1948-49	1949-50	1950-51	3 Yr. Avg.
Controlled	5.6 pH	658	355	1048	687
Uncontrolled	4.3 pH	284	195	561	348

It would appear that, if soil analyses are of value in indicating nutrition levels available to citrus trees, production should be greater where the soil reaction has been controlled. This is substantiated by yield records for the past three years in these plots as shown in Table 3.

Yield records reveal a 97.5 percent increase in production during the past three years. This has evidently been due to a higher level of nutrition maintained through pH control as revealed by soil analysis.

As mentioned previously, fertilizer applications were equivalent on both treatments. It should be stressed, however, that a large number of soil samples spread over a long period of time (13 sample dates during one year) are required to show true differences thus eliminating fluctuations due to rainfall and fertilizer applications.

The conclusion from such studies would be that controlling the soil reaction on the acid sandy soils planted to citrus through the use of adequate but not excessive basic materials is of great importance in providing for increased utilization of applied fertilizers.

THE LIME REQUIREMENTS OF ORNAMENTALS

R. D. DICKEY *

Experiments designed to give information on the lime and nutritional requirements of ornamental plants under Florida growing conditions are, so far, few in number. Considerable work has been done, however, with other commercially grown plants, for example, citrus, vegetables, tung trees and avocados, which show that these plants respond by better growth and yields to fertilizer applications. It is to be expected that the miscellaneous group of plants used as ornamentals would also respond to fertilizer applications. Many observations attest this fact. It follows, therefore, that any management practice which would maintain or improve the fertility level of a given soil would be advantageous to the plants growing therein.

The exchange capacity of a soil is a good index of its ability to absorb and retain a group of important plant food elements designated as "exchangeable bases". Several factors influence this ability, but for light, sandy soils, particularly, two of the most important factors are pH and organic matter content. Some control can be exercised over both of these important factors because organic matter can be added and the acidity of acid soils can be reduced by the use of lime.

Work with citrus and vegetables indicates that on sandy soils a pH range of about 5.5 to 6.0 is best for the maximum retention and use of the exchangeable bases and that this is usually reflected in better growth and yields of these commercially grown plants. This being generally true for citrus and vegetables, it is likely that many ornamentals will respond similarly, that is, they will attain their best growth and appearance on soils that are not extremely acid in reaction. There seems little doubt that many ornamental plants growing on sandy, clay or muck soils that are very acid in reaction, would benefit from the application of lime either in the form of dolomite or agricultural lime. This point is of importance because much of our ornamental plantings are on acid sandy soils.

Soil reaction plots were established at Gainesville, Florida, on light Arredondo soil in 1926. The pH reactions determined in 1940, which are representative of the pH levels throughout the experiment, are given in Table 1. In the initial applications, sulfur was applied to treatments 1 and 2 at the rates of 1000 and 500 pounds per acre, respectively; treatment 3, untreated check; treatments 4 to 6 were given applications of limestone at the rates of 1000, 2000 and 4000 pounds per acre, respectively. Smaller amounts of sulfur and limestone were applied in 1931, 1935 and 1937 to maintain pH at the desired level. Three commonly grown ornamental plants, severinia, *Ligustrum lucidum* and Rosedale arborvitae were planted in the soil reaction plots in June, 1938. The growth responses of these plants as measured by the average height of plants in the treatment is given in Table 1. The data suggest that these three species of ornamental plants, if grown on sandy soils having a pH of about 5.5 or lower, would benefit from the moderate addition of lime.

* Florida Agricultural Experiment Station, Gainesville, Florida.

TABLE 1.—GROWTH OF THREE ORNAMENTAL PLANTS IN SOIL REACTION PLOTS

Treatment No.	Treatment pH	Ornamental Plant (Height in Inches) Severinia	*Ligustrum lucidum*	Rosedale arborvitae
1	4.48	12	15	11
2	4.66	15	16	13
3	5.41	26	29	22
4	6.07	30	41	25
5	6.59	33	39	23
6	7.34	28	40	24

Planted June 30, 1938, measurements taken May 27, 1941.

Barnette and Mowry (1) reported on a controlled experiment with the Formosa variety of azalea which was started in 1931. A sandy soil with a relatively low content of organic matter and an original pH of 5.76 was placed in 4-gallon glazed pots and adjusted to give different degrees of acidity. They found that below pH of 5.00 the plants made a slow but healthy growth and the foliage was dark green. The plants grown between pH 5.00 and 6.00 were healthy and twig growth was lengthened which produced a larger but not spreading plant with dark green foliage. Between a pH range of 6.00 to slightly above 6.50 the growth was rapid with distinctly elongated stems between the whorls of branches which produced a somewhat open sprawling type of plant. Foliage was healthy and flowering normal. A distinctly unhealthy plant condition was observed at pH 7.00 and above evidenced by shortened growth with distinctly chlorotic leaves and sparse foliage. Experience with azaleas growing under field conditions indicates that when the reaction of sandy soils, particularly, goes above a pH of about 6.00 the incidence of iron deficiency, with its resulting unhealthy plant condition, is considerably increased.

Gammon and Wilmot (2) reported their experiment on soil acidity and camellia growth. By the use of a nutrient medium with artificial zeolites they were able to establish in 4-gallon jars, artificial media which had a theoretical pH range of 3.0 to 8.0. One plant each of four camellia varieties was established in each jar. A picture of the jars used in the experiment and the plants growing in them showed that all the plants in the pH 8.0 culture were dead and only one plant of four survived in the pH 7.0 jar and it had made poor growth. Those plants in the jars which had a theoretical pH range of from 6.0 to 3.0 appeared healthy. They state that it is not known whether the poor condition of the plants in the pH 7.0 and 8.0 jars was due to the high sodium content. Camellias have often been referred to as one of a group of so-called acid loving plants. Under field conditions, however, both healthy and unhealthy plants have been observed at a wide range of soil reaction. This seems to indicate that they are not as likely to develop physiological troubles incident to overliming as they have been given credit for and should not, as is frequently done, be listed along with azaleas as being especially intolerant of alkaline soils. It is possible that camellias would also benefit from the application of lime to very acid soils.

Ornamental plants are usually grown in locations that make cultivation and fertilization as practiced with tree or vegetable plants difficult if not impossible. Those individuals who plan on landscaping their own grounds may have the reaction of their soil determined. If their soil runs much more acid than a range of pH 5.5 to 6.0 it would probably be advisable to adjust the pH to this range by the addition of lime. This could be done for shrubs and trees by applying the lime to the area to be occupied by the root systems of the plants and working it into the ground before planting. It is much more difficult to adjust the pH of the soil area about established woody ornamental plants, because little if any cultivation can be used to incorporate the lime in the soil and Volk and Bell (4) have shown that the penetration of lime is very low.

The amount of lime to apply will vary depending upon several factors, some of the most important of which are pH of the soil. organic matter and clay content, base exchange capacity, the soil reaction to be attained and the liming material used. The information that is needed to determine the amount of lime to apply to adjust the soil reaction to the desired pH is given by Volk (3) in Press Bulletin 606.

If there were no other consideration than the addition of lime. the best material to use for this purpose would be a high grade agricultural lime. However, the acid sandy soils of Florida usually run low in magnesium so there is the ever present possibility that magnesium may be at or near the deficiency level for some ornamental plants. Because of the possible need for magnesium, dolomite should be given preference for ornamental plants because it will satisfactorily adust the soil reaction and at the same time supply magnesium if that element be needed.

The ill effects of overliming light sandy soils in Florida have been stressed in recent years. With ornamental plants this trouble is usually present naturally on the alkaline sands of the coastal areas and the marl soils of extreme southern Florida. A condition of overliming is often produced in very localized areas as the soil immediately adjacent to the walls and foundations of brick and stucco buildings often becomes alkaline in reaction. Mortar may be mixed with the soil in the foundation planting area about buildings as a result of construction operations which produces localized overlimed areas. These possibilities should be kept in mind by those attempting soil reaction adjustments on acid soils in residential areas.

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PANEL DISCUSSION: SOIL AND WATER CONSERVATION OPERATION AND PLANNING IN THE EVERGLADES AREA AS INFLUENCING SOIL SUBSIDENCE AND ULTIMATE LAND USE CHANGE*

Leader: W. TURNER WALLIS, Chief Engineer, Central and Southern Florida Flood Control District, West Palm Beach

Co-Leaders: LEO L. BURNET, Chief, Engineering Division, Corps of Engineers, U. S. Army, Jacksonville and HORACE A. BESTOR, Consulting Engineer, Clewiston

Secretary: R. V. ALLISON, Belle Glade

Dr. I. W. Wander, Vice President of the Society, acting in the absence of President Carrigan, called the meeting to order and turned the chair over to R. V. Allison, Secretary of the Society and of the Panel.

R. V. ALLISON:

The unusually good attendance this evening, including, as it does, so many growers and others directly interested in the life and welfare of our Everglades soils, is a better evidence than any other of the importance of the subject we are about to discuss. I dare say there are few present in this room who do not know of the perishability, under drainage and use, of the ogranic soils that make up the broad expanse of the Florida Everglades. In other words, these soils are like the cake which we cannot eat and keep. In this instance we cannot farm these soils and keep them for this purpose thru that indefinite and endurable period which we like to associate with well-managed lands.

Since the plan of the discussion is quite fully outlined in the sheets that have been passed out and will doubtless largely hinge on an analysis of this report[1] (holds up copy) on the "Subsidence of Peat Soils in the Everglades Region of Florida" that recently has been compiled from existing information by Messrs. J. C. Stephens and Lamar Johnson, I should like without further ado to turn the meeting over to our very capable discussion leader, Mr. W. Turner Wallis. Turner knows the physical and financial problems of the Everglades, including the many complicated angles of tax structures and zoning, better than any other man in South Florida. We are fortunate, indeed, that he is able to be with us and lead the discussion this evening.

W. TURNER WALLIS:

Thank you, Dr. Allison. The one thing I'm not going to do is to reveal in advance what the speakers are going to tell you and thus spoil their talk. I hope everybody who is interested will not fail at the conclusion of this meeting to take a copy of this report to which Dr. Allison has made reference and which is largely to be the basis of the discussion this evening. We are purposely not giving these reports out until after the meeting as we don't want you to be distracted by its reading from what the several members of this panel have to tell you.

In order to get into the substance of this meeting most expeditiously and effectively I believe it will be helpful if you are first given the background of the work of research and the assemblies of information that have gone into this report. The analysis of that information and the predictions based on that analysis will

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* This entire discussion is from a tape recording except where otherwise indicated.

[1] Subsidence of Peat Soils in the Everglades Region of Florida, compiled by J. C. Stephens and Lamar Johnson. For the reproduction of this report in full from the replicated form in which it was first prepared for distribution and study see, appendix page 191.

then follow. Consequently I am going to call first on Mr. J. C. Stephens of the Soil Conservation Service, U.S.D.A., who is stationed in West Palm Beach for the conduct of studies in the general field of this discussion. Before calling on Mr. Stephens I'll appreciate it if the other speakers who are to be called will occupy these chairs in a semi-circle so they will be more readily available to the questions from the floor.

MR. STEPHENS:

This is the report Dr. Allison and Mr. Wallis have referred to that has to do with the "Subsidence of Peat Soils in the Everglades Regions of Florida." I do want briefly to give you a little of the background of this work and I'll tell you just a few things that are in it—not everything, of course. In fact I won't even undertake to outline it in detail.

As indicated by the title, this is a report on subsidence of peat soil under Everglades conditions. All peat soils when they are drained subside or lose elevation and, insofar as we know, they continue to do this throughout the life of their drainage and use. Thus England has been draining such lands for I would say well onto a hundred years and these have been losing elevation at the rate of about 1 inch per year. Likewise the delta soils of the San Joaquin Valley, Sacramento and Stockton, California, have been under cultivation for some time and according to the reports from the State Experiment Station out there, they have lost about 3 tenths of a foot. or a little over three inches per year. Much of this, we are told, is associated with the deliberate burning of the surface of the land between crops or seasons for various reasons including control of weeds as well as diseases and insects.

The Department of Agriculture in 1915, knowing of the expected loss of peat soils under cultivation began an investigation of this subject in the Everglades. At about that time a number of what will be referred to as subsidence lines were run at different strategic locations in the Everglades including the Davie as well as the Okeechobee area, and out onto peat soil around Fellsmere. These were lines of levels anywhere from 1.000 to 5,000 feet in length tied into a base level at some point. These have been re-run at regular intervals since that time and you will now find in this report several graphs showing subsidence and consequent loss of surface elevation of the soil at these points thru the years. These lines, of course, reflect the subsidence of the land as its occurs in nature. Some of the loss has been due to burning, yes, and some to compaction from mechanical operations but most of it doubtless is due to natural oxidation. In any event these lines show what is actually happening and what has happened in the Glades.

Later, I believe it was about 1931 or 32, Mr. Clayton, who was here at that time, and Dr. Allison and others who were at the Experiment Station, layed out a series of controlled water-table plots on the Experiment Farm.[2] That is, these plots were laid out in such a way as to permit a close control of the water tables in the soil at definite elevations and hold it there throughout the period of study, which was some seven years. The results of these studies have definitely shown that the amount of subsidence in soils of this nature is a direct function of the depth to the water table. In other words, the lower the water table, the more rapid the subsidence. By this trend was fully indicated the desirability of holding the water table as high as feasible depending upon the crop returns. In this experimental setup yield of crops was of course measured to obtain returns on maximum as well as minimum depth to the water table.

Incidentally, along with the measurement of the loss of the surface elevation at the various levels of the water table, the carbon dioxide released from the soil also was carefully measured. It was found that the amount of gas given off by the soil under these various conditions could be correlated directly with the loss in elevation, or, with the loss of soil substance. This naturally brings up the critical question of "What causes Subsidence?" There are, of course, three or four causes for this irreversible trend, all of them accentuated by drainage.

The number one cause of subsidence, as mentioned earlier, doubtless is loss by oxidation, that is, by a slow chemical and biochemical burning. In other words organic material is not only oxidized under the influence of the light, heat and air of normal field conditions but there are certain microbes in the soil that live on

[2] Mr. F. E. Staebner, Associate Drainage Engineer in the Bureau of Agricultural Engineering at the time, who was specializing in irrigation studies, preceded Mr. Clayton in the assignment by the Bureau for a period of two or three months and helped very greatly with the actual setting up of the water table studies.—Ed.

organic matter of this type as a source of energy. Thus carbon dioxide is produced and the soil is slowly burned up.

The second important influence on soil losses under these conditions is thru rapid oxidation by fire. While this form is more conspicuous and spectacular, on the whole it is much less. In other words the losses from free burning have been much less than from the slow natural type of oxidation. Then there is the loss of elevation due to compaction as from natural shrinkage following drainage and farming operations. This usually occurs most rapidly during the first or second year of operation on the land and feathers out after the fifth year. Actually, however, this form is not so much a loss of actual soil mass, just volume. It does not concern us too much because after the initial compaction is over it does not go on and on at a fairly constant rate like that due to natural oxidation.

We have found from these water table studies, then, that the soil loss is definitely a function of depth to the water table. In other words the amount of air that is penetrating into and circulating thru the soil is a very determining factor at all times and under all conditions. Thus we have found that when land of this type is drained to a given depth, if you have it cropped on one hand and hold it undeveloped, on the other, the uncultivated sawgrass land will actually lose soil mass faster than the cultivated land. The reason for this obviously is that when the land is cultivated and compacted the circulation of air through it is reduced. Therefore, when once you drain a soil of this type it is axiomatic, in the interest of conservation, that it should be worked down and put under cultivation as soon as possible. As soon as we found this out then one of the first things that came into question was, what is happening out in the Glades, the so-called open virgin Glades, that haven't been cultivated and, supposedly, have not been drained even tho they had surface water on them only a portion of the year. How much soil are they losing? Is the water table high enough out there to prevent the loss of soil by oxidation?

In an effort to answer such questions we took the old levels that were run when the canals were first surveyed through the Everglades in 1912. Incidentally, we also had a contour map that had been made in 1942 showing the depth to rock Then, too, we had the survey made by the Everglades Drainage District in 1925. Furthermore, we had the surveys made by the Soil Conservation Service in 1941 and 1942, as well as the recent survey made along the levee and canal alignment by the Corps of Engineers, U. S. Army, quite recently. By superimposing these various sets of values we were able to get at the amount of loss that was occurring in the so-called wild land. While we might be able to reconcile ourselves to the losses occurring in the cultivated areas it was distinctly disturbing to learn that the wild lands were losing soil mass and surface elevation at a considerably more rapid rate.

In consequence of the above findings the obvious conclusion was that a water control program which would enable the lands to receive water from Lake Okeechobee or other reservoir areas should be instituted as soon as possible so that the land either could be put under cultivation and the greatest possible gains realized from it during its lifetime of usefulness or else a higher water table be maintained in or over it with the view of giving it the greatest possible protection until it is needed for active development.

Mr. Johnson, I believe, will carry the discussion forward from this point.

Mr. Wallis:

Thank you, Mr. Stephens. I think it would be helpful to the cause of this discussion if anybody who has a question upon the conclusion of the remarks of any speaker would not hesitate to ask that question; or if those in the group who are more familiar with this whole problem than some of the others may feel that there is an important point that has not been brought out, I would appreciate very much their raising such point or points as they or others in the audience may feel have not been made as emphatic or discussed as fully as they feel should have been by the speaker. Before I ask Mr. Johnson to continue. does anyone have a question that they would like to ask Mr. Stephens at this time?

Mr. Johnson:

For nearly one hundred years now, the people of Florida have dreamed of farming the Everglades. They have had the feeling that if they could just get out there on that rich land there could be developed one of the greatest agricultural areas in the world; and it truly has become that, within certain limits.

However, the old timers who first entered this great area found that peculiar things began to happen. For instance, every few years Bob Creech would have

to put an additional step on his house because that bottom one was forever becoming too high. He had to add another one to get down to the ground. And Bob has recognized that. The farmers out there have known it; they have known for some time that the land is losing elevation.

Mr. Stephens has told you something of why our peat lands are losing elevation: why they are losing volume. However, he didn't tell you much about the rate at which these black peats are going down. We believe the studies back through the years that he briefly outlined to you conclusively indicate that, on an average, and mark you well those words, ON AN AVERAGE, you can expect a loss thru the normal use of the Glades lands of about one foot every ten years. Again you should mark well the use of the word, NORMAL. Thus, if you had started out in those early days with soil as deep as 12 feet some of those same soils, today, because of over drainage, bad practices in agriculture, fire, and the several factors that enter into it, have lost as little as four feet and as much as six feet or more of their original depth.

Just to see how long our dream of farming the Everglades would last we proceeded to apply what we have learned up to the present time regarding subsidence. In other words, on the basis of the present soil depth remaining we have projected land use into the future along with these tendencies towards subsidence according to what we have learned from the records of the past. In this projection we assumed the lands now in cultivation have taken their initial loss and would only lose in the future say, on the average, one foot in ten years. On the wild lands, the lands that are not in use at the present time, you heard Mr. Stephens tell you just a few minutes ago that they are losing mass at a substantially more rapid rate than the soils that are now actually in use. In this forward look, therefore, we based future loss on these lands, on the assumption that they would be cultivated and put into use, within ten years— that is by 1960. At least most of us are optimistic enough to believe that if the water control program goes through as it should the whole of this presently uncultivated area within the diked agricultural section of the Flood Control Plan (points to map), will all be in use by 1960. We have also assumed that those wild, unbroken lands, because of the loss of mass they have already experienced under partial drainage, would take their initial loss soon after they are put into cultivation. This has been approximated at a foot and one-half for the first ten years and from then on they would lose elevation at the same rate as the land that is now in cultivation.

The projection of these losses was made through the years over the entire agricultural area of the Everglades. Through these projections it was found that by the year 2000 most of the agricultural area enclosed by dikes would probably have to be abandoned unless some way can be found of substantially retarding that average loss of approximately twelve inches every ten years. We assumed naturally that when the soil reaches a depth of one foot over the rock, that it no longer could be economically used, even for pasture, because of the difficulties in draining and also the difficulty, in the dry season, of properly getting water to it.

Along the margins of the glades where the peat is over sand or marl or a mixture of the two we do not have this problem because you can continue to farm those lands after the peat is gone just as you farm the sand lands of the Davie area or some of the areas marginal to the Everglades behind the Lake Worth Drainage District where in times past there was a cover of from one to several feet of peat. However, where the soil is underlain by rock it looks as if by the year 2000 most of that area cannot possibly be farmed economically. That means, of course, that we must develop these glades lands as rapidly as possible; to mine them for everything they are worth if we are to get out of them their total value as a natural resource so long as they last.

Two things, therefore, are necessary, quickly, if we are to get the most out of those peat soils. The first, is the completion of the water control system that the Corps of Engineers is now constructing. This should be completed as quickly as possible and put into operation so that the farmer on the land will have sufficiently complete water control to permit him to practice the greatest possible degree of conservation on his land thru the most efficient use of water.

We need another item very badly that is not mentioned in this report which I would like to bring to your attention at this time. Along with the development of a water control system we need a road system which the Corps of Engineers cannot provide under the Flood Control Plan; but they can be helpful. Those channels that they propose to put around and through that agricultural area will

be of great depth and considerable width. There will be an abundance of material available from them for the construction of roads. THE WATER CONTROL SYSTEM AND THE ROAD SYSTEM SHOULD BE DEVELOPED HAND IN HAND and we must have both of them as quickly as possible if we are to salvage all that we should from what remains of this great land resource. Thank you.

MR. WALLIS:

Those of you who know Lamar weren't surprised when he laid it on the table in the most horrible form that he could think of to express it. There is room for a lot of difference of opinion whether the rate at which subsidence has occurred should be projected ahead and be taken as a criteria for future trends in this respect. I hope those of you who have an honest difference of opinion with Mr. Johnson will give voice to that opinion at the appropriate time.

On the other hand, I do not feel that enough emphasis has been given to the real value of this report and the credit that is due those who have made it possible. I think this work is an outstanding credit to the Experiment Station, the Soil Conservation Service and all the other agencies that had the foresight to plan work of this nature as early as this research work was planned. Mr. Johnson and Mr. Stephens, who are the authors of this report, had as their immediate concern the consideration that should be given to subsidence of the land in the design of physical works proposed under the plan of development for the whole area upon which we are now working. They have done a job far beyond the call of duty in making available the results of earlier experimental work in this way and in making available, under this one cover in the nature of a progress report, the material contained in many other excellent reports prepared through the years on this general subject. I hope that they, and others having a similar background, will make available to the literature on this area many other such reports in the future.

According to the schedule in which we are calling on these speakers to give you a cross section of the significance of this whole problem, I now would like to have Mr. F. D. R. Parks discuss how the problem is viewed from the Engineering standpoint in the lower reaches of the Everglades area of which Dade County occupies such an important part.

MR. PARKS:

Mr. Chairman, Ladies and Gentlemen: As you are probably aware, most of my time is spent in the flood control program down in the Miami area, and this is influenced to quite a considerable extent by the tendency of organic soils to shrink under drainage and use. First, however, I want to make a personal correction on this program. I am not the County Engineer but more of a water-control engineer instead. Mr. D. A. Anderson is the County Engineer in Dade County and in charge of the program I am talking about. We also have a salt encroachment situation in the ground water supply down there that is related to this subsidence problem in a way that I will tell you about.

First of all, I would like to emphasize that we have some good marl land down in South Dade County. I emphasize this because I don't want to leave the impression that we don't have any good, permanent farm land down there; that all of it is going to subside like some of our lands out in the Everglades do. In other words we're going to have a "bread basket" down there when much of what we now have in the back country has largely faded away.

As most of you know we have some very low areas that people try to farm right around the City of Miami, 2 to 4 feet above sea level. This, of course, gets in the way of our salt encroachment program because we have some dams in the canals to back up the water and to hold the freshwater head high enough above sea level to keep salt water out for purposes of safeguarding our well and domestic water supplies which come from large wells and for commercial industries along the canals themselves. We have some farmers in this area, so-called farmers, for they do farm part of the time, that is sporadically. They like the land that is right close to the canal and so they try to farm in this area. Think they, well, this water is backed up on us in a way that hasn't been observed earlier.

It is precisely on account of this water control program that we have made some detailed field measurements in a few of those areas. Some of the older measurements or levels were made not with that in mind. However, the newer ones were made with this problem very definitely in mind and it was found that over some of those areas during the past 11 years the surface of the land has subsided 0.9 to 1 foot, which falls very closely in line with the chart that Mr. Stephens and Mr. Johnson

came up with on the rate of subsidence in relation to the depth to the water table. They made that comparison for the few points we have measurements on and have found that several of our points fall on one side of the curve and a couple on the other side. And so we find that our subsidence values fall pretty close to the averages they have established. Consequently, I think their observations and conclusions are all right.

There is another point of particular concern to us. We have another problem down there that is quite different from that around the lake area in the Upper Glades in that we can't pump effectively either for drainage or irrigation. We have a seepage condition, a very porous underlying rock, that makes the situation exceedingly bad because we cannot nearly provide the degree of water control that can be practiced in the Upper Glades area around the lake. I believe that is all I have to say about this general problem right now. Thank you.

MR. WALLIS:

Thank you Mr. Parks. Does anyone have a question they would like to ask Mr. Parks? I will now call on Dr. Herman Gunter, State Geologist, to discuss how the geology of Southern Florida influences the water conservation problem and consequently, the soil conservation program in this extensive area.

DR. GUNTER:

Mr. Chairman, Ladies and Gentlemen: Dr. Allison did not give me but six months to prepare for this discussion so I am therefore at a bit of a loss as to what to say and how to say it! (Laughter.) Naturally enough, I turned to colleagues of mine down here in the Miami territory for help because the U. S. Geological Survey has cooperated with the Florida State Geological Survey in the study of the geology and hydrology of the southern extremity of peninsular Florida almost continuously since 1930 or 1931. Much of the detailed knowledge of the geology of the area was developed during this study and these notes are largely based on unpublished work of members of the U. S. Geological Survey, particularly Mr. Melvin Schroeder. And so, between us, in this particular instance, this statement has been prepared which I hope you will not mind our reading just to keep the facts straight and in order to get through on time.

*The area under discussion by this panel is a part of a larger geologic unit that includes most of the Everglades as far north as the northern Broward County line and the coastal ridge from West Palm Beach southward along the entire lower East Coast. In general, these formations compose a mass of sediments that lie upon the Hawthorn formation of middle Miocene age, and which are generally thickest in the coastal areas.

GEOLOGIC FORMATIONS

These shallow formations are the foundation upon which the soils of the area have been developed by deposition of peat and by the weathering of these rocks. The rocks compose a single hydrologic unit of permeable materials ranging in age from upper Miocene through Pleistocene. The base of the aquifer is set not by formation boundaries but by differences in hydrologic properties of the sediments, and is placed at the top of the impermeable greenish marl of the Tamiami formation. The following formations, from oldest to youngest, are present: the Miocene Tamiami formation (permeable portions), Caloosahatchee marl, as small scattered erosional remnants and isolated reefs of Pliocene age, and the Pleistocene which is represented by the Fort Thompson formation (southern part), Key Largo limestone, the Anastasia formation, the Miami oolite and the Pamlico sand.

TAMIAMI FORMATION

The Tamiami formation which crops out at the surface in Collier County underlies the entire southeast Florida area. The formation is divisible lithologically and hydrologically into two units. The lower unit is composed of impermeable greenish marl and constitutes the top of the artesian system in southern Florida. The upper portion, a very shelly, marly sand, where it has locally been altered by ground water to a highly permeable solution riddled sandy limestone of calcareous sandstone constitutes the basal part of the aquifer of the area.

*Taken from a prepared statement from this point.

CALOOSAHATCHEE MARL

The Caloosahatchee marl is known to extend southward from Lake Okeechobee for several miles where it occurs as thin permeable limestone and sandstone reefs or shoe-string sands.

FORT THOMPSON FORMATION

The Fort Thompson formation is the chief component of the South Florida aquifer. In Dade and Broward counties the formation is predominantly light gray to cream-colored fossiliferous, marine, sandy limestone and calcareous sandstone with thin inter-beds of gray and tan fresh water limestone. The entire section has been subjected to solution by moving ground water so that the material is a cavity-riddled mass of very permeable rock. Cavities may in places reach a few feet in diameter and are sometimes filled with sand which tends to decrease permeability. In general, the sand content increases toward the coast.

The Fort Thompson formation is one of the most highly permeable rocks in the world and compares in permeability to very clean well-sorted coarse gravel. It is the chief source of water for larger producing wells in Dade and Broward counties.

ANASTASIA FORMATION

North of Boca Raton in coastal areas and a few miles inland the Anastasia formation forms a large part of the aquifer of the coastal ridges. It is usually composed of sandy limestone, calcareous sandstone and shelly sand, in part coquinoid, with the amount of sand increasing in coastal areas. The formation has also become riddled with solution cavities by ground-water movement, so that it is an excellent source of water in coastal areas in Palm Beach County.

KEY LARGO LIMESTONE

The Key Largo limestone forms the Florida Keys extending from Soldier Key southward to include Bahia Honda. It is relatively unimportant since it usually yields salty sea water to wells. It is composed mainly of coral heads and other reef building material of very permeable character.

MIAMI OOLITE

The Miami oolite is the surface rock which blankets nearly all of Dade County, parts of eastern and southern Broward County, the southern mainland area of Monroe County along with the lower Florida Keys and a small area along the Collier-Monroe county-line. The Miami oolite is usually a white to yellow oolitic, cross-bedded limestone containing varying amounts of sand usually in cavities. In general, the formation is less permeable than the underlying Fort Thompson formation. However, it is the source of supply for many shallow irrigation wells in the Miami area.

PAMLICO SAND

The Pamlico sand is a fine to coarse terrace sand deposit which covers much of the Everglades north of the approximate latitude of Fort Lauderdale, and blankets coastal areas as far south as Coral Gables. It is a shallow source of supply for small sand point wells.

OCCURRENCE OF GROUND WATER

All the water which supplies southern Florida is derived from local precipitation. When rain falls to the surface a part is evaporated, a part is used by plants, a portion runs off into lakes and canals, and the remainder percolates downward through surface materials to the water table. The water table is the surface below which the rocks are completely saturated. Ground water is stored in openings in the rock and moves laterally and vertically under gravitational influence to points of discharge in streams, canals, lakes and oceans. It is this natural discharge which maintains surface water body levels during dry seasons.

The water contained in the ground-water aquifers occurs under non-artesian or water table conditions because no impermeable material overlies the aquifer and the water in a well penetrating the aquifer will not rise above the point where water was encountered. The water table is represented by the water surface in wells and holes which are deep enough to penetrate it.

The water table fluctuates in response to rainfall in the area and may vary considerably from year to year. Also, the water table within the year is high during the rainy season of May through October and low during the period of November through April. It is during the period of low water stage that soils are deficient in water, oxidation is greatest and the aquifer underlying the coastal areas is subject to accelerated salt water contamination from the ocean.

GROUND WATER USE

The shallow formations are the important non-artesian source of water in southeastern Florida. Nearly every municipality in Dade, Broward, and Palm Beach counties taps this highly productive reservoir for its municipal supply. In addition, thousands of smaller wells are drilled into the aquifer for domestic, irrigational, industrial, cooling or stock watering purposes.

Water wells are moderate in cost since usually little casing is required to complete a well. However, in coastal areas where sand is more prevalent, more casing and sometimes screens are necessary for completion. Wells may be pumped at high rates over long periods of time and, due to the high permeability of the aquifer, only small drawdowns will result.

The ground-water pumpage in 1950 for the three counties is estimated at 140 million gallons per day. Of this total Dade County consumes about 100 million gallons per day. Following is an estimate of the various usages of ground water in Dade County for 1950 in gallons per day:

Municipal	65 million
Industrial	20 million
Rural and irrigation	15 million

The above total pumpage for 1950 is nearly twice the amount consumed in Dade County in 1945.

It is expected that in the near future the daily water use in this same area will exceed 200 million gallons. This demand can be obtained from ground water, provided that certain conservation steps are taken in some areas. It is this phase of the general question of water supply that ties in so directly and so definitely with the subject of this panel discussion.

Mr. Wallis:

Thank you, Dr. Gunter, for that paper. Interspersed though it was with all those 5-dollar words it was still quite readily understandable. I think that it was very helpful in drawing the physical picture that we are trying to develop with the many complex relationships which exist in this extensive problem.

Mr. John Pickett, who I know Luther Jones, if he were presiding, would refer to as the "muck rat", will now discuss the transitions that have been observed by him during his many years in the Everglades and give you his opinion of what we should expect in the future.

Mr. Pickett:

Thank you Mr. Wallis and Mr. Jones for that really "down to earth" introduction. I didn't realize that you and Luther could place in me such an exceeding amount of trust. Gentlemen, as I think of this problem before us, I am reminded of one of the remarks of Sir Isaac Newton when he said "As I play along the seashore picking up pebbles, picking up a shell more beautiful than the rest, I pay no attention to the great sea of truth that lies before me." I have studied this very excellent report by Messrs. Stephens and Johnson very carefully. I have gone over it with the view of trying, if possible, to tear it to pieces. Unfortunately, gentlemen, I concur. I can find little in it of which I can disapprove.

However, in studying the initial shrinkage of the Everglades soils, that is, as shown by sections taken before 1924-1925, I've found myself confronted with this question. In making such physical observations as surface elevations on these glades while in a virgin state during those early years are they accurate and at all com-

parable even to those of more recent years. In other words, gentlement, no soil you ever stepped on could be less stable, for if you stood on the soil *here* it would rise up over *there*. The question of the engineer always has been, therefore, "where and how should we hold the level rod?" That is to say, if we were to take the elevation of what should be regarded as the very top of the parent soil, should we set the level rod down and let it come to rest by its own weight? In all of this I am reminded of a conversation I had with one of the first men to run a level over the Everglades, a Mr. Richard F. Ensey of Stuart, Florida. He informed me he had nailed cross laths to the bottom of his level rod so it would not sink and that in this way he could get the true surface elevation of the glades. But now, gentlemen, was this the true elevation? When first the drainage came in what did we lose? Did we lose actual soil mass or did we simply lose elevation of water?

In studies that have been made since 1924 and 1925 I have no argument or question. In fact I have observed this subsidence thru the years but have never made nearly as careful study of it as these gentlemen have. However, I have noticed different rates of subsidence and must agree to the influences causing them. Therefore the only real hope I can find in this report that is under discussion this evening is the observations made in respect to the influence of high water tables on this tendency. Thus for over a period of ten or 12 years there was practically no subsidence on those plots at the Experiment Station. In fact, as I recall, that particular graph showed only 3/100 of a foot or a rate of loss of only about 1/100 foot in 3 years. That, gentlemen, I consider to be very small. On those particular pasture plots, too, you could have seen some very fine grass even with the very high water table that was maintained. Such findings I consider very much worth while.

I am very much disappointed, however, in all these studies to find that they were made only on "saw grass" and "willow-elder" types of land. In other words I saw no graphs on the subsidence of the so-called "custard apple" muck. It is my opinion that there exists, possibly in the files of the County Engineer, Jake Boyd, certain soundings that have been made showing depth of this muck using the rock and the canal levels as the datum. This is from the vicinity of Hendry County, around past Ritta, on around the south shore of the lake and up the southeast shore as far as Canal Point. If there is any possible way to obtain these early records I think it would be well to do so. It would indeed be fine if Palm Beach County would make these records available to the proper supervisors and testers. It would be a great public service, and would give us the basis for a very excellent report of a similar nature on this type of soil. The above soundings were made in saw grass peat, willow and elder peaty-muck, and custard apple muck over a distance of at least 35 miles. So I very strongly urge this committee or group to take steps to ascertain the availability of this data and information. Thank you.

Mr. Wallis:

Thank you, John. Mr. Mounts will now present observations relating to this problem that he has made as County Agricultural Agent of Palm Beach County through a quarter-century of extension work in the Everglades area.

Mr. Mounts:

Mr. Chairman, Ladies and Gentlemen: Unlike Dr. Gunter, I didn't have 6 months notice of what I was going to talk about when I got up here. In fact I found out what I was supposed to talk about when the Chairman introduced me as I stand before you this evening. Dr. Allison mentioned to me about a week ago that he would like to have me on this panel, and he told me this afternoon that I was on it. And so this evening I found out that I am to make some comments on what I have observed in the quarter century that I have worked with the Agricultural Extension Service in Palm Beach County.

It seems to me that the problem of subsidence can be reasonably well projected into the future—as to what will happen and what can be expected in the years to come, from the use of these lands. It is true that we have made a lot of progress in the Everglades in changing over from a strictly vegetable type of agriculture to one involving the development of extensive areas of pasture land. The comments that have been made and supplemented by John Pickett concerning soil subsidence trends under pasture conditions give us some indication of what we may expect or at least of what we could do in the future. In my opinion, therefore, it is going to be a matter of the proper utilization and management of these soils and the formulation of an opinion as to what investors can expect to do with them in future years.

As your County Agricultural agent I have had a great many inquiries about the possibilities of agricultural development out in the Everglades and so we present and discuss with them this plan of the U. S. Army engineers. However, until we really get the so-called agricultural area enclosed and the control facilities operating efficiently there isn't too much that I, as the County Agent, can tell these people regarding these lands, especially those lying back from the roads in the really undeveloped sections. And so, until we have some assurance that the water control facilities are going to be installed and the roads built reasonably soon there isn't much that can be done except to listen to the talk of speculators. But I, as County Agent, am interested in people who are going out there to develop these lands and make sufficient money from these essentially rich soils to pay for the cost of this extensive flood control program that we are seeing projected right here this evening. And I have every confidence that if this plan is developed, as I know it can be, and will be, that we can get these lands developed and that we can develop them as rapidly as Mr. Johnson, here, has suggested that they should be; also that we will be able to utilize them in a way to make them pay off in an economically sound and successful manner. Thank you.

Mr. Wallis:

Thank you, Mr. Mounts. The next several speakers are those actually using the land, dirt farmers, so to speak. I think there should be much interest in listening to their viepoints and learning what plans they may have to cope with the problems that have been outlined by the previous speakers. We would like first to hear from George A. Wedgworth, a young farmer from the Belle Glade area whom we all know very well and whose father, before him, we knew even better.

Mr. Wedgworth:

I don't feel that I am really very well qualified to get up here and undertake to speak to you on this subject. In fact, I must apologize for not having prepared a talk. To tell you the truth I feel more like a student, with you as the instructors; and I want to sit back and ask questions.

I do have one important question that I would like to have answered before I leave tonight in that, to me, it is a very pessimistic report which states that by the year two thousand most of the lands of the Everglades will be totally unproductive or will be right down on the limerock. That is decidedly pessimistic because I have been rather hoping still to be around at that time and such a viewpoint leaves me a bit up in the air as to what I will be doing then. They haven't given me any answer as to prevention or cure.

I think one of the good points that has been brought out was by John Pickett in his remarks about these subsidence trends on pasture lands. I have noticed the same thing on two of our farms under pasture development where pasture areas happen to be next to celery fields in which the water table is held relatively high. While there hasn't been a level put on the surfaces of these soils, it is apparent just from simple observation that there hasn't been nearly the subsidence in these pasture lots with a fairly high water table that there has been under cultivated land. I believe that if we look at this whole question from the standpoint of pasture development it will be a little more optimistic than Mr. Johnson puts it. Frankly, Mr. Johnson scared me tonight, but I guess that either he or I will get straightened out before the evening is over.

Mr. Wallis:

Thank you very much, George. That was a very helpful contribution. We will now hear from Mr. Harrison Raoul who has had a great amount of experience with widely different types of agriculture in the Everglades and is presently manager of Hillsboro Plantation that is located well down in the middle Glades.

Mr. Raoul:

I am inclined to agree with my friend, George Wedgworth, and hope Mr. Johnson gets himself straightened out before the evening is over. I represent a company that has a very substantial investment in muck land in the Everglades. This is a long term investment. We didn't come in to make our money quick and then get out. We didn't come in to mine this good land, Mr. Johnson notwithstanding. And I sincerely hope we can do a better job than that with our holdings. Frankly, I think that we can. I also feel, with equal frankness, and this certainly is a self-criticism on farming in the Everglades, that though I've only farmed here twelve years, I am now certainly conscious of having mined the land while I have been out there—

from a drainage standpoint as well as others. This is because I just haven't known what I was doing. Now these studies have been made and certain very important trends have been brought to our attention and we begin to see what we are doing to our own natural resources.

Now we are told that there is nothing we can do about it. that it is going on and on in spite of anything we can do. Well, I just frankly refuse to believe it. I think we *can* do something with scientific brains at the back of this problem; and I certainly hope that our company can make its contribution towards doing it. The first way we are trying to do something about it is this. We are told, and we certainly have observed that if you can maintain a high water table in your cultivated area your land does not subside as fast as it does if you keep a low water table. So therefore, what crops can you grow on a high water table?

It seems to me that is the first obvious solution if we are going to farm and not mine the land; keep a high water table. Well, we find that celery grows well on and, in fact, requires a very high water table; so we're growing a lot of celery. We also find that kenaf, though a rather new crop, has a lot of water tolerance and will grow in the summer time when it is quite easy to hold a high water table, and so maybe it is another crop. We don't know for sure whether kenaf will grow forever and ever in the Everglades, but we are certainly interested in the crop and willing to try it.

We also find that maybe there is a possibility of growing rice in the Everglades. We are not too sure that we can get this crop to grow but we do have two eighty-acre experimental plots under way and right now we think that it might do quite well. Of course we would like this very much because you grow rice under at least partial flooding. Now I don't know any better way to keep the land from subsiding than what these gentlemen have told me, than keeping it under water. So therefore, it seems to me that rice might be a very good crop if we can work the problems out that are connected with its culture. Please understand, we are not ready to say that we can grow rice yet, but we are ready to say that it looks like we can and the possibilities certainly should justify further investigation.

Cattle, yes, we have found that our pasture, particularly our permanent pastures, do much better with a high water table than they do with a low water table insofar as producing tonnage of grass and hence more beef per acre, and that is the business we're in, growing more beef per acre.

So, we certainly think that vegetables such as celery and others with a high water tolerance have a very important place. We also think that such a fiber crop as kenaf also has its place. And we believe that rice may have a very definite rotational place in our program. Finally, we firmly believe, from the long-term investment standpoint, that our investment is sound and can be carried on. Thank you.

MR. WALLIS:

Thank you, Harrison. We will now listen to Mr. Luther Jones, publisher, realtor and erstwhile farmer.

MR. JONES:

I knew that I was going to be here but I didn't know that I was going to be called on. However, I am glad I am. As a newspaper man and as a real estate peddler this report did more than scare me. I have been active for the past six or eight months trying to induce wealthy Yankees to come down here and invest some of their money. Now, how am I going to tell them that this land is not going to last for more than fifty years, some of it much less. I feel something like Harrison. I have a great deal of respect for Lamar and Mr. Stephens but I'm not going to let myself believe what they have said.

Now there is a great bunch of what I would like to refer to as Brass Hats present. PhD.'s, why these are as thick around here as fleas on a Vinegar Bend dog; and it is hard to get any of you to make a definite statement so anybody could pin you down.[1] And yet I love every one of you and the work that you are doing

[1] May it not be that the *statement* which has been made long since and repeated many times by his friends, "The Brass Hats", regarding the unavoidable subsidence, under drainage and use, of organic soils such as make up the vast reaches of the Everglades, and which is the principle topic of discussion this evening, is already *TOO definite* for Luther? In any event, it will be interesting to see what he has to say from here on out.--Ed.

because I have induced a considerable number of well-to-do gentlemen from the north, during the past several months, to put their money in this muck we are talking about tonight. And it is only because of my confidence in you and in what you are doing that I can go back and face any of them tomorrow despite Lamar's and Stephens' report. I'll tell you why. I have a great deal of respect for American ingenuity and American brains. And I'm telling you gentlemen here tonight that I expect you to disprove what Lamar Johnson and Mr. Stephens have said, I expect you to show us a way out. I know there is a way out. And I expect you to show us that way. We have an inkling of how it is to be done but we don't know for sure and I know that you same gentlemen here tonight within five minutes are going to begin to tell us how to do it.

Suppose it is fifty years. You can pay for your land in five years and you've got forty-five years left to make a profit out of it. Now honestly, gentlemen, I have a great deal of confidence in the ability of men such as yourself coupled with farmers like Wedgworth and many others in the Glades to find that instead of the year 2000 it will be 2050. However, for me, along with some of the rest of you who haven't any more hair than I have, the year 2000 is not going to hold a great deal of personal interest. But there will be farmers out there in the year 2000: and I believe there will be those out there on the land who will be farming the Everglades in the year 2050.

There is one thing I want to say to Dr. Allison and to the Soil Science Society of Florida and it is this: Representing the Florida State Chamber of Commerce, as Chairman of its Water Control Committee, I want to thank them for bringing these problems before us and having them discussed. That is one of the ways we are going to find the cure. Now Lamar and Mr. Stephens remind me of the doctor who tells an old gink my age or a little older, who has had heart trouble, that according to the records he will most certainly lie down and die within five years, or between now and then or maybe day after tomorrow, if he don't change his ways. We are not only going to change our ways of farming in the Glades but you, gentlemen, are going to tell us how to do it. I thank you.

Mr. Wallis:

Thank you Luther. After such a confession we know you are going to live to a ripe old age. We will now listen to Mr. John Tiedtke.

Mr. Tiedtke:

I am glad Luther Jones spoke first because he said about everything I had to say and now I don't need to take up much of your time. I have had enough experience with farming in the Everglades to see that the land levels are actually down a little.

Some of our fields that we used to be able to mole drain satisfactorily, cannot now be drained in this manner; and some of the fields that we used to run a dragline down inside of the ditch now have to be dynamited. So in my short span of farming in the Glades, subsidence has been observed to be a little more than a rumor. However, it took this report of the engineers tonight to turn it into a concrete fact that you can measure and I must say that I was startled by several things in it. Not because the rate of subsidence was any greater in the tables of the report than the things that it seems have happened out on our farms, but because they have been working on the thing since 1936.

I feel that since it does take a number of years to develop something that a Ph.D. will put his name to we are all very fortunate for the foresighted vision way back in 1936 that got this study going so that today we have this report. In 1936 and 1937 none of the farmers that I knew were talking about subsidence. If they knew about it they didn't seem concerned about it and there was apparently sufficient foresight on the part of the Agricultural Experiment Station in those days to justify starting an experiment that would hold water, figuratively as well as literally.[5]

This report, I think, is extremely valuable. It seems to me that if we can do all the miraculous things we do, make all the tests we make with all manner of bugs,

[5] As an indication that serious thought had been given to the subsidence of Everglades soils under drainage and cultivation long before 1936, a part of the summary of the first bulletin of the Everglades Experiment Station (Fla. Expt. Sta. Bul. 190, 1927) is reproduced on page 190 of the appendix of this volume facing the recent report on this subject which was discussed at length during the evening and which is reproduced in full on pp. 191 to 237.—Ed.

bacteria, viruses, etc., if there is a certain type of action going on in the soil that we don't like, someone ought to be able to think up a way to stop it. I really do have hope.

As far as the general task is concerned, practically, I think we have two entirely different problems. They have been mentioned briefly. One is that of the farmer whose interest, as a citizen, is to make an investment in the land he has and to come out with a little more than he put into it each year. We have all the good wishes in the world for posterity but we do have to eat and so we have to go out there and find a way that will pay off. So we are going to have to find the best way possible, of course, for successful land use but the plan also has to be practical from a day to day standpoint.

However, from the standpoint of acreage a far greater problem lies in the vast expanse of undeveloped Everglades peat and I will touch on this only briefly. I agree that is not an additional problem if it means the simple destruction of the land. However, I think that, without any question, it is a matter of conservation of natural resources and that conservation is certainly going to be worth the money it will cost to put this program into effect. I'm not at all sure that the Flood Control Program is going to prevent all flooding. There are some of you here who know much more about this than I do and can answer that question much better than I can. But I do believe that it is within the purview of the Federal Government's interest to jump into this problem with both feet because the time may come when we are not just feeding the present population of the United States. It is possible that we may be feeding 50 percent more people 50 years from now and this land will then have ever-increasing demands made on it for the production of greater and greater amounts of food for consumption at home as well, perhaps, as abroad.

Mr. Wallis:

Thank you, Mr. Tiedtke. Now I'd like to call on Mr. Leo L. Burnet, Chief. Engineering Division, Jacksonville, Fla. District, Corps of Engineers, U. S. Army. Jacksonville, Fla., to present to you the viewpoint on this problem of his Corps as an agency of the Federal Government.

Mr. Burnet:

Mr. Chairman, Ladies and Gentlemen, this is the first opportunity that I have had to appear before the Soil Science Society and I want to say right here that I really appreciate it. As many of you know, I'm a very far cry from an expert on the conservation of organic soil. I'm sure that I'm going to learn more tonight than I'm going to contribute.

[a] However, I'd like to refer back to may first encounter with organic soils which was about 35 years ago when I was in an Army Camp in New Jersey. They had land there they referred to as bogs, or sometimes cranberry bogs because they used to grow cranberries on them. The cranberries grew on little bushes just a few feet high. They had these bogs arranged so that they would flood them in the winter. cranberry bushes and all, to a depth of several feet. They would freeze over, and I have often gone ice-skating on them. When spring came they would remove the boards of the temporary dams, drain the water off, and the cranberry bushes would leaf out, bloom, and bear, without damage from being inundated.

Many of these bogs contain peat. From childhood association with families who had come from Ireland, I learned that on many of the farms in Ireland they had peat formations which they would use for fuel, cutting the peat in slabs similar to our lawn sod, drying it, and storing it for winter use. I had visions of developing a big business as soon as I got out of this man's Army in the matter of mining this peat. I got a shovel and sliced out a cubic foot or two of the material and put it aside to dry. It was soaking wet and seemed to remain that way for so long that I almost forgot about it. When I did look at it a month or two later, it had shriveled up to about nothing, and looked something like Grandpa's beard.

I next encountered organic soils in Wisconsin, where they were also referred to as bog land. They were not covered with water, but the water just about stood on the surface and the earth seemed to rise up in circular mounds. If you would jump on them, the mass would quake. This proved be very valuable farm land when drained, and the drainage seemed not to present a very great problem as the area of the bogs was quite small. They would simply run lines of 6-inch drain tile, about 50 feet apart and around 4 feet deep, draining the main line off into a ditch.

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[a] Taken from a prepared statement from this point.

My first knowledge of the Florida Everglades came from my grade-school study of geography. The Florida Everglades was described as a vast area of slimy ooze, literally crawling with crocodiles and all sorts of poisonous snakes, lizards, and what-have-you. The very name Everglades was mentioned in a hushed tone as being something that denoted horror, destruction, and death. We were led to believe by our teacher that if one ventured so much as to stick his foot in the Everglades he would soon be sucked into it, and if poisonous demons didn't get him first, he would be sucked under, and his remains would be discovered at some future geological age.

The Glades land suitable for long-time agriculture, now generally known as the agricultural area, is amazing in its productivity when properly drained. Unfortunately, as quickly as it is properly drained oxidation commences, with the resulting subsidence or lowering of the surface. I am sure you will all agree that this subsidence is a known fact wherever organic soils are drained. Since the initiation of the Central and Southern Florida Project for Flood Control and Other Purposes, the Corps of Engineers has made hundreds of laboratory tests on the organic or peat soils. While there is some small difference between the different classes of peat, such as Everglades Peat and Loxahatchee Peat, generally speaking our tests indicate that the field moisture content in terms of oven-dry weight is about 600 percent. The oven-dry weight amounts to only 8.6 pounds per cubic foot. More important, the average organic content we have found to be 77 percent. In other words, if we would take a sample, then dry it, determine the dry weight, then burn it, we would find that 77 percent of the dry weight would burn up. We can therefore say that 77 percent of the peat lands is subject to slow oxidation when drained. Complete oxidation of a peat bed with an original depth of 4 feet would leave only 1 foot. The subsidence of peat soils under cultivation is real and indisputable, whether those soils be in the State of Florida or any other place in the world. While a great deal of very valuable research has been done to determine the rate of subsidence, that rate still must be considered a variable amount. The rate would vary in different parts of the country, due to varying climatic conditions. Right here in Florida the research I have already mentioned indicates considerable variation, depending upon to what use the land is put. Thus, lands subject to a high state of cultivation subside more rapidly than do those used for pasture lands. Those used for certain crops subside more rapidly than those for other crops. However, it seems apparent that the rate of subsidence of our drained Florida organic soils is very closely associated with the depth of the water table maintained in those soils. The lower the water table, the greater the subsidence, and vice versa. Therefore, the best possible conservation of our organic soils would demand the maintenance of a water table just as high as the crop being grown will permit, with a still higher water table when the lands are idle.

We of the Corps of Engineers like to feel that we have earned the name of being public servants. I say "earned" because I don't believe anyone is entitled to be called a public servant unless he actually *serves* the public. In this public service, it is absolutely necessary that we take cognizance of the problems connected with farming organic soils, including the matter of subsidence, and I would like to explain briefly just how we are so concerned and what we are doing about it. In the agricultural area we are going to dig many canals with levees on each side. These leveed canals will serve as the main drainage arteries in the agricultural area. Water will be fed into these canals by privately owned and operated drainage works to serve the adjacent lands. In turn, the water will be removed from these main canals by large pumping stations, to be installed by the Federal Government. The levees on each side of the main canals will be built on top of a layer of peat with varying thickness, depending upon the location. Some of the levees will contain peat in the embankment, but it is our present plan that all of these levees will be covered by a minimum 2-foot thickness of rock and marl. To allow for the subsidence and compression of the peat, the construction grade or crown elevation of the levees will be increased in the amount of 50 percent of the depth of the peat contained in or beneath them. Thus, all of the peat in the levees or below the levees can subside by 50 percent of its depth and the levees will still be high enough. Then the problem is, what is going to happen when these adjacent lands subside some time in the future? Will these main canals still function as drainage ways for the adjacent lands after they subside? The answer is "Yes", although the adjacent landowners may have to pump against a little higher head as their lands become lower. If at some future time the agricultural lands subside to the extent that pumping costs are greatly increased, and it would become economically feasible

to deepen the canals in order to lower their surface water profiles, it should not be too difficult to have a study authorized in the way of a review report of the project towards determining whether the canals should be deepened. If such a review report would indicate that the cost of deepening the canals will be offset by appreciable benefits, it appears likely that Congress would authorize such work, just as it has been doing for many years in the past in connection with navigation channels. It is very often the case that Congress has authorized the construction of a navigation channel to a certain depth and then in later years, based on the findings of a review report, has authorized a deepening of the channel. In some cases they have authorized the same channel to be deepened several times as the needs of navigation require. Whether it will become necessary at some future date to lower the main canals due to subsidence of the lands is anybody's guess. It might be found that as the land subsides, large areas would go out of production and therefore out of drainage and the water profile of the main canals will be lowered automatically due to less water being fed into them.

We would indeed be delinquent in our planning if we did not take cognizance of the possibility of deepening the canals at some future date in the design of our large permanent structures such as the pumping stations. In view of the expected subsidence of the organic soils in the agricultural area, our planning of the pumping stations provides for a possible future lowering of the canal profiles by several feet.

Mr. Wallis:

Thank you, Leo. In promising to refrain from telling you what the speakers were going to say, I didn't say I wasn't going to make some comments after they've said it, in an endeavor to interpret or comment on their remarks. I'm very much impressed by Luther's reference to this discussion appearing to him like the situation where the Doctor tells a patient about a critical heart condition and if he doesn't mend his ways he is at death's door and won't be here for even one year. I think there is a lot of truth and thought in the analogy he drew in this connection because those who have the heart condition and don't get to hear of it from the Doctor and do what he tells them, usually don't last that long. I think that is a good message for those of you interested and concerned with the welfare and conservation of Everglades soils. You first get yourselves scared good and hard, perhaps somewhat unduly, and then you had all those fears allayed by the PhD.'s, referred to by Luther as the Brass. I don't know why there was no mention of Bureaucrats in this connection as they are usually associated in Luther's remarks with situations of this nature.

Be that as it may, there is a definite part in this program of conserving, developing and using our Everglades land resources to the very best advantage that rests on the individual owners of the land. I only hope you won't be the patient that got scared of your heart condition but didn't do anything about it. There are very definite levels of responsibility in this, but the big share of it, in my opinion, rests on the individual. There is a certain responsibility and a very definite but limited one, that has been accepted by the Federal Government and other agencies, both State and local.

Furthermore, I don't think quite the right interpretation has been placed on what Mr. Johnson said. Mr. Johnson tried to emphasize that with subsidences of from four to six feet in depth in the approximately 45 years since there has been any attempt at reclamation of the Everglades, there has been a loss, as best it can now be ascertained, of about 40 per cent of the original depth of the muck over this area; and that there is obvious need for something to be done along very carefully planned lines in the immediate future. He endeavored to emphasize that even with the projection into the future of past rates of subsidence that there is still an asset that warrants a most definite call for greater protection and more skillful utilization. At this time I'd like to call on Horace A. Bestor to present an overall summary of his views on this subject.

Mr. Bestor:

Mr. Chairman, members of the Soil Science Society, Ladies and Gentlemen: I am glad to comment on this devastation of the organic soils of the Everglades as observed thru the years of my personal experience in this remarkable area. When I was given a copy of the report that has just been reviewed, naturally I was very much interested in reading it. In doing so it gave me a very vivid impression that it is an inventory of facts representing something that is happening that is cause for real concern.

However, I'm like Mr. Jones, just naturally an optimist. I can recall coming to the Everglades when it was entirely under water. I can also recall making an examination and study of the use of the land at that time. One of the first impressions that I developed during those early days while the Everglades was still largely under water, was the great need of the land for the conservation of that water. I based such a prediction of necessity that was not too obvious at that time, on the facts of rainfall, which occurs in Florida only about 25 percent of the year, thus leaving approximately 75 percent of the year practically without rain. Therefore, before the land was converted into the vast agriculture empire as we know it today around the shores of Lake Okeechobee, the thought that was uppermost in my mind was, water conservation in relation to the moisture that was needed the year around.

This, then, was my first interest in the problems of organic soils. However, I don't know that "soil" is the right term because an organic mass such as we are working with is not properly a soil in the conventional use of the term. As a matter of fact, when you start to work with such body of decomposing and decomposed plant material you are really in a sort of soil building business! In other words, you will have to put into the material something to balance its fertility because such highly organic peats haven't much in the way of natural fertility, except nitrogen, of course—and water. I was particularly impressed with the fact that in such an organic mass under natural conditions its greatest constituent is water, and if you should take that water away from it you will have some real problems on your hands, immediately, especially in the form of an almost unbelievable degree of shrinkage.

Another of the impressions that has endured from those early days and which might enter into this problem in a practical way was that in the different areas that I had to work with in the Everglades where they were trying to move water there was no place I could find where they talked in terms of moving volumes of water; they were talking largely in terms of a "10-foot canal" or a "50-foot canal", and when one asked the meaning of that, well, that was a "big canal" and should be able to take care of a lot of water!

Now I feel this way about Florida. Florida's assets are largely her climate and her abundant supply of good water. And jolting as this report sounds with regard to our being out of business in the Everglades in the year 2000, I don't believe that, especially when you recall that there are various kinds of business. As a matter of fact I don't find the main points that are contained in that report to be particularly new if you look back thru the various reports having to do with the reclamation of the Everglades such as those of the Department of Agriculture and many others made during what we might call, for want of a better term, the "dark ages". Practically all the comments ever made on the possibility of using Florida's organic lands were adverse. It couldn't be done; and they talked in those early days about this subsidence of the land surface that we've been discussing at length this evening.

There is no denying the facts of this inventory. It is a drastic picture and has much meaning However, the principal conclusion that I've developed thru the years in trying to compromise the use of this land with its ultimate destruction as a forthright agricultural asset is that you have to care for it through its water. Furthermore, if you are going to be successful in soil building on this land you can be sure that it is going to be a very painstaking job. We can't continue to exploit it as we've been exploiting it in the past. In order to make that point in a report that I made on how to handle water, I spoke particularly about a place to put water. I'm speaking now in reference to my experience in developing all the drained areas that border on Lake Okeechobee and of having to do with making studies of how to handle the land in relation to water. Such studies were based on the actual quantities of water that had to be moved. In designing those canals, there were certain depths, and certain elevations and certain operations that had to be considered which would preserve the growing quality of the soil and the necessary equilibrium between the soil and the water. So it required a lot of time in designing and laying out a system which would service the lands both in relation to drainage and irrigation requirements thru those periods during which the rainfall was in excess or insufficient.

Now to get more directly at a description of what organic lands are in terms of the sawgrass peat of the Everglades which we are largely discussing, it must be remembered that it was developed through thousands and thousands of years of growth and dying back and growth and dying back of the native sawgrass into the

organic mass. On this account the structure of this soil is largely vertical to that growth. In all the practical experience I have had in the manipulation of water in relation to the growth that made that organic material is was found to be vertical, the movement of the vegetation in falling down being negligible. This means that such structures should always be taken into account in any and all operations designed to move the moisture thru the soil whether in (irrigation) or out (drainage). Anybody that has anything to do with handling water under these conditions understands that for it isn't a new theory. It's a fundamental fact that has to be faced.

The story of this loss by subsidence isn't new, as has already been observed. It dates back to the "dark age" referred to earlier. It has been told to the people of Florida from the beginning. When I came to South Florida I promised exploitation of the soil resources of the Everglades, and I don't view that as any more serious than I do the exploitation of its waters. The water supply of Florida is being exploited and destroyed in the same way as the organic soils. The principal reason we are losing our lands is because we are not paying attention to the fundamental facts of how they must be handled. That isn't something that some long-bearded scientist is going to tell us some 5 or 10 years from now; you have been told that for the last 25 years that I know of through my own experience.

Now they tell you that there are other causes for that loss and there has been some proof that all of that loss is not necessary. The operating of your pumps and the control of your ditches is, of course, your responsibility but it has been the too common thought that if the ditches were pumped dry you had more of a chance for drainage from the land or you could pump that ditch dry and then not pump for another week and save a few dollars. If you were to operate your water system like we had planned and as it should have been handled, a large portion of that type of operation would have been avoided.

Another thing is that in efforts at conservation of these organic lands the soil must get back just as much of the organic material as possible that has been taken out of it through cultivation. You can restore or prevent a good deal of the subsidence by putting back all the plant debris that can be made available for the purpose. In doing this please keep in mind that as you return these materials to the soil and otherwise maintain its fertility you are adding to the stabilization of Florida and to the ultimate realization of this great plan of reclamation. In my opinion the land can be saved.

Now you've got another drastic type of loss in the use of organic soils. Let us consider virgin land. The first time you remove water through drainage you are going to initiate a natural compaction. Thus in the 12 years of experience on organic soils with which I've had to do, that initial loss has amounted to about a foot in the first 18 months of drainage when the free water actually leaves the top soil and settles down into the more compact soil. Of course you have not lost anything like that amount of material, it has been largely water and elevation that has disappeared. In another 24 to 30 months that same type of compaction loss amounts to about another foot and one-half. That is the experience that I have had in the development of the drainage districts I have had something to do with.

I have also had something to do with some of the experiments being carried out, for instance certain studies that have been carried out by the Experimental Station; and I have listened quite carefully to the discussion of water tables. I have the feeling that there is a misunderstanding of what the water table actually means. It certainly don't mean that you can have the water table right up near the top of the land as Mr. Raoul has said. In any event such high water tables will certainly place definite limits on what you can do. They also limit you as to the rate at which you can move water. Furthermore, I don't care what kind of plant growth you put on any kind of land and particularly organic land, of course, it can't do anything at all unless the roots can breathe. The greatest factor in handling water in soil is not to waste your moisture and provide irrigation in that soil only to such a degree that when the roots go down into it they will still find a breathing space. Thus, if you have what is commonly known as a "high" water table within your land all the roots of most plants that go down to that water table will assuredly make an effort to turn up. More likely they will die. These roots under such conditions will turn up for the simple reason they must have air and there is no oxygen, whatsoever, in the ground water of such soils.

Another important point to keep in mind in designing the water control features for a particular area and that is whether you are going to raise rice, celery, beans, or sugar cane, because the requirements of these crops are God-given and you must

deal with them in figuring your reclamation requirements. It becomes a matter of handling a certain amount of water under certain conditions. The principal overall condition in South Florida is, of course, the exceedingly flat terrain with which we have to work. So, regardless of the crop that you decide to grow, the fact remians that your ultimate design must be based on the true requirements of such crops and not on some quick whim that you are simply going to raise certain crops. All of this, of course, does not need to be confused with the factor of water duty to a plant. There is a vast difference between the water requirements of vegetable crops, such as celery, and that of sugar cane or some other crop, both in their structure and in the way they get their water and their food from the soil.

Now if you are going to drain land, drain it in a true sense, that is, you are going to regulate the moisture in the soil in a way that will provide an optimum balance for the life processes within the plant. If you choose, therefore, you can design a proper system of water control for an area regardless of the type of vegetation that is to grow on it. The thing that most particularly limits the kind of crop you are going to plant is the fact that you know you can't raise crops not adaptable to this latitude and general climatic conditions. Insofar as your moisture condition is concerned you have got to stabilize the factors which balance that moisture for a particular crop. Unfortunately, the best stabilization of moisture in the soil (a reasonably low water table) brings about the alarm you cannot use organic land in that way, that it is inevitable it is just going down and down and down until you come to the zero plane. If this be true then there is no need for any 208 million dollar project to try to control the remaining resources and rebuild them. I don't believe that is true. I do believe, however, that Florida lacks one of the greatest factors and that is a reclamation law which will require a controlled handling of her fresh water resources. If it is left to the individual to do just as he wants to do and handle the water in any way that he may choose then no amount of scientific study is going to help what I regard as a very critical situation. Thank you.

MR. WALLIS:

Thank you very much, Horace. There are two things which give me complete confidence that there will be a solution to this and many other problems confronting this area. One of them is a certain group of people who never hesitate to give their full and unqualified support to such public causes whenever and wherever the occasion demands. We have several of that group here tonight. I would like to have them stand if for no more than to take a bow. We would love to hear from them if they have something they would like to contribute. The other factor that gives me so much encouragement is the so-called Brass Hats or Bureaucrats as Luther Jones affectionately calls them. After agreeing on the objectives of this program, that is, the program for water control and the conservation of our water and land resources, they may then have wide differences of opinion from that point on. So that which is scheduled to be done must be warmly defended against objections and criticisms, both pro and con. I don't think anything has been done lightly or will be done lightly or will be done without the need to plan and full criticism of those plans. Those whom I would like to have stand for a bow are Bob Creech. John Bollinger and Ralph Blank. They are all typical of the solid support this area and this program have had. The support they have given in the past will be called upon again in the future. It affords a large part of the confidence I have that this and other problems will be worked out. What have you got to contribute, Bob?

BOB CRLECH:

Well, I am somewhat like Luke. I came in here on the 19th day of January 1919, in fact I was one of the first passengers on the Coast Line Railroad. My uncle met me with his mulemobile—we didn't have automobiles in those days, and no roads. I believed in this country then and I believe in it now.

I will give you a concrete example on one farm that I have operated for 30 years to prove that land will not subside if it is properly taken care of. On the other hand, I don't think that it would have been possible to do more damage if you had gone out with the intention of burglaring and dissipating and destroying property. There could be no more complete job than has been done in the Everglades since I have been there. I see very little regard for the future use of that land from the way many have been operating it in the past.

Consequently, I have been called a fool many times for many things that I have done, one of these being for planting a cover crop every year. It has cost me about

ten thousand dollars just to plant that cover crop to try to protect my soil, eliminate weeds and insects, keep land free from root knot and attempt to put back on that land every year as much plant material as is removed from it by oxidation; and I can give you concrete proof that I have actually done that for over a period of 30 years

In 1905 M. D. Garrett, one of the men who made a survey of Lake Okeechobee, ran a level on Ritta Island. When that land was homesteaded elevation levels were run on the meander line at approximately the 17-foot elevation. I went over there in 1922 and was going to get rich in a hurry growing celery. We started off fine. Since 1927 that land has had a uniform water table—not one of these jump-up-and-down kind. We go over there in the fall and if we have to pump in or out we establish a uniform water table. We plow under those cover crops—we do not burn them off—we prepare those lands and hold a uniform water table during the entire life of that crop. Following the harvest the cover crop is again planted within a week or ten days. This has been carried on now for a long period of years. With another pumping station taking water off the low ground I now maintain the same water table all over the farm; not too high to drown my crops, but high enough to grow them. I tell you, gentlemen, that land is properly taken care of. And I say it is a fact because today on Ritta Island I've had less than six inches of subsidence in 30 years. I have owned the land now for 30 years, farmed it for 30 years and I know what I'm talking about. The meander line surveyed in 1905 with a 17-foot elevation today is 16½ feet.

I am not discouraged at all about the Everglades. I don't think we will need to be flooded. The main thing we need, and I have watched these operations over a period of more than 30 years—we need a uniform water table. And this can come about only through a much closer regulation of the water in the whole area, including Lake Okeechobee. Thank you.

Mr. Wallis:

Thank you, Bob. It now gives me very sincere pleasure to recognize Mr. John Bollinger who has certainly been a tower of strength at every turn in the development of this soil and water conservation program.

Mr. Bollinger:

Mr. Chairman and distinguished visitors: I have been very much impressed by the opinions of the scientists and of the engineers to whom we have been listening. The land that I used to plow (up in Georgia) was greatly troubled by washing away. In recent years I have observed that they have devised a plan whereby they can protect that land against such washing and now they are producing more crops on it than they did at the time I used to plow. I firmly believe that the scientists and the engineers that we have here can certainly devise some plan whereby our valuable soil in southeast Florida can be preserved.

I well remember attending the meetings of the Soil Science Society in 1942 and 1943 when this question of soil oxidation and subsidence was of very great concern to us and extensively discussed. Now you have the scientists and Director Fifield of the Experiment Station here who can give you full and complete information on how to build up your soil like they did in the first land I used to plow. They can give you that technical information through the Experiment Station arm of the University of Florida, where some of the finest scientists in the world are to be found. You also have some of the finest engineers in the world here. You can combine the knowledge of these two groups and I submit to you, that approximately 50 years from now you will have built a new soil and it will continue to do what the Lord intended it to do and that is to feed the population. With such a combination of technical and scientific knowledge I have a profound and abiding confidence that exactly that can be done, that actually you can stop the subsidence and proceed to build your soil so that it can continue to feed the people.

It is a delight for me to be here again this evening at the Soil Science Society's meeting. I hope that I may be privileged to attend it regularly from here on out. I intend to stay in this part of the country and, of course, the backbone of this section is the productiveness of the soil. I am indeed happy to be here.

Mr. Wallis:

Thank you, John. We are also certainly honored tonight in having Director Fifield with us, and greatly appreciate the effort required for him to be present. We also greatly appreciate the interest he and the entire staff of the Experiment

Station and of the University have shown in our problems. I don't know if Director Fifield may care to make any remarks but I would like very much to have him stand so that those of you who don't know him will be able to recognize him when you see him. We also have another very good friend of this area. Col. Matthews. Chief Engineer of the Division of Water Survey and Research at Tallahassee. Last but not least from a point of service. I want to call on Ralph Blank. Manager of the Palm Beach County Resources Development Board.

RALPH BLANK:

Chairman Wallis, it would seem that the subject had been very fully covered. I just want to say that we owe a debt of gratitude to Lamar Johnson and Mr. Stephens who bring us this challenge. Though they have brought us a challenge, they have not discouraged us in any degree. I happened to be Chairman of Governor Caldwell's Water Conservation Committee in 1946. In the course of the State-wide conference held at Lakeland that year Governor Caldwell said that it is going to take some great disaster in order for us to get water control improvements on their way in Florida. This was almost a prophetic remark, because, in 1947 the fearful flood that came and which so greatly accelerated the flood control program because of its disastrous results seemed almost a fulfillment of his prophecy. And I believe that this treatise that has been prepared and discussed by these gentlemen is going to do the same thing for our soil conservation problem; its going to invoke the ingenuity not only of the scientist and of the engineer; it is also going to challenge each and everyone of us who have our all invested in the Everglades section of the state. We are indeed grateful to all these gentlemen for this thorough discussion of a highly important problem here this evening.

MR. WALLIS:

Does anyone have a question? Or a comment they would like to make from the floor? If not I'm going to call on Dr. Allison to (interruption) QUESTION FROM AUDIENCE (Bob Creech).

Since you are the head of the water control outfit, can you give us any idea why the sudden reversal on the thinking of the elevation of Lake Okeechobee. That is what a lot of us are vitally interested in.

MR. WALLIS:

Why Bob, I'll be glad to schedule a meeting on that at Belle Glade for a discussion of the studies that are under way and the alternate plan in mind. I think that it is a rather lengthy question to go into now since there is no change that has been decided upon there are a number of studies of the best way to accomplish the objectives of the program, which I think would be very much in order to discuss at a public meeting. If the Water Control Committee of the Resources Development Board may care to sponsor such a meeting I'll work with them at any time or place.

BOB CREECH:

I know this is not the place to bring up this subject. The only thing I have in mind is that since a lot of people here have been to other meetings previously with representatives of the Flood Control District I should like to have them take a note that in the event we have to raise the level of the Lake, we will have to redesign every pumping plant around the Lake at a tremendous cost. Now, gentlemen, you may not know what I'm talking about, so let me explain just this one little thing to you. This whole program was set up and based on the Lake having a 5 foot head of water: the entire set up of the whole drainage district was based on a maximum 5 foot head of water. We ran into this in 1947, there wasn't a single pump capable of handling the water. We are bucking an 8-foot head right now and our motors are burning up. Now they may have some engineering, or other good reason. You people are land owners, and I want you to know some angle of this has been brought up at every meeting, because I've been to every one.

The minute you go over a 5 foot head of water your motor is overloaded. Now this is a serious thing that I'm talking about and when it comes up for public discussion, I'm going to be there and I'm going to ask the full support of all citizens even if we have to go to Congress to prevent any such thing as this. I may be crazy, I'm just a dirt farmer, but you can't make me believe as your land goes down that it is necessary to pile the water higher and higher to make me do more seepage

pumping. When the first rain comes, the water table is gone and crops are drowned out and you can't pump it off.

MR. WALLIS:

Bob, let me point out one thing. The present limits in reference to the control of Lake Okeechobee are a 3-foot range, between elevations 14 and 17 on Okeechobee datum. It's been proven that Lake Okeechobee, with present facilities, can't be fully regulated at that narrow range. The current studies have determined the range in which it can be regulated with the expenditure of the amount of money that can be justified. The indications are that it's going to take nearer a 6-foot range; and study is under way to determine what that range will be. Elevations of 10 to 16 on the present sea level you use, would mean 17.4. However, let's say for the sake of argument, that isn't the final decision. There are months of study and field investigation before that will even be recommended to the District office, to the Division or to Washington. But let's say that a range of 10 to 16 becomes substituted for the present 14-17, the encouraging thing about that is there will be facilities provided to hold it within that top range and you know as well as I know that while 17 is the prescribed height you have had 14 more than you've had 17. So there isn't any cause for concern, because it just hasn't been possible to regulate the lake within those limits. If the upper limit should be set at 17.4 representing 16 on mean sea level it will be held within that range and you will be much better off than you have been. However, nothing has been done in connection with this program that has been kept secret. There has been no final decision, and if it is the pleasure of the people in the Lake area to be brought up to date on those studies and the alternates under consideration, that's their privilege and I'll be glad to arrange it. However, let's not get strung out on a question that would last till morning. Now, does anybody have a question or comment from the floor?

AUDIENCE:

Chairman Wallis, Mr. Johnson touched on the subject of what we need most to do. He said the most important thing is the earliest possible development of the organic soils within the agricultural area, but that in order to do this we need roads. I notice on the program that under item number 8 we were to learn something about those roads. I wonder if anyone here can tell us about them.

MR. WALLIS:

Unfortunately it seems that there is quite a conflict of other programs this evening and the gentlemen who were listed on the panel for this particular subject (Merrill P. Barber, Vero Beach, and Paul Rardin, Canal Point) could not be here.

MR. RAOUL:

Is there not something that we can do in the absence of these gentlemen even if it be only to prepare a carefully considered resolution setting forth the sentiments of those present regarding this question of roads?

MR. WALLIS:

Since the discussion of the principal subject of the evening seems to have been concluded I should like to turn the meeting back to Dr. Allison who can carry on from here.

DR. ALLISON:

Thank you Mr. Wallis for the splendid job you have done in leading the discussion. We are also indebted to you for the good help your office has extended in making a record of this discussion possible. This, of course, will permit its inclusion in the published Proceedings of the Society. Now with regard to the question that has been raised by Mr. Raoul regarding item 8 on the agenda, I am inclined to agree with him and with Mr. Johnson as to the importance of having a substantial Road System follow very closely upon and, in fact be fully integrated with the development of the proposed Water Control System. In fact such a relationship and requirement would seem to be of almost axiomatic simplicity. Is there any discussion of Mr. Raoul's suggestion regarding the desirability of a resolution on the subject?

LUTHER JONES:

Mr. Chairman, are you inviting a resolution about roads?

CHAIRMAN ALLISON:

Inasmuch as you are Chairman of the Resolutions Committee of the Society, Luther, it would seem that you should be able to operate in this connection with a considerable degree of freedom, especially since the need for such a resolution is actively under consideration.

MR. RAOUL:

Mr. Chairman, if in order, I'll make a motion. I don't know if any of these good people are going to ride on these roads we are talking about but I am sure they will support the idea in principle. I now move you, Mr. Chairman, that the Resolutions Committee be instructed and empowered to draw up and distribute a resolution requesting Federal, State and County authorities to look carefully into the feasibility of constructing a publicly maintained road on top of each dike to be built by the Central and Southern Florida Flood Control District wherever such roads will become a desirable and necessary part of a transportation system required for the development of this area South of Lake Okeechobee as shown on this planning map of Central and Southern Florida Flood Control District.

LUTHER JONES:

I second it.

CHAIRMAN:

Is there any discussion? Are you ready for the question?

CLARENCE BAILEY:

There is one more angle that I haven't heard discussed much tonight and that is cooperation between the County Commissioners and all of these flood control operations. I just want to touch on the development and maintenance of County Roads and water control ditches along two especially new developments. I'm referring to the Willard Smith road which was recently made to his development out there. There are, of course, several others. I went to Jake Boyd, the County Engineer, to find out what the plans were and he said the Board of County Commissioners of Palm Beach County are not interested in taking care of water control. Now it appears to me that if they are not, we don't need the roads. We need the water control as much as we do the road, the new roads in particular, and vice versa.

CHAIRMAN:

It would be my thought that the resolution under discussion will cover such a question as you have raised; at least I hope so.

MR. BAILEY:

That's the reason I wanted to bring it out. I would also like to ask what sort of distribution this resolution will have if and when drawn.

CHAIRMAN:

It will of course be published in the Proceedings of the Society. It's distribution otherwise will naturally be according to its content and according to those to whom it is decided to send it as incorporated within the body of the resolution. Such distribution cannot be made, of course, until after it has been published in the Proceedings. Does that answer your question, Mr. Bailey?

MR. BAILEY:

Yes, very satisfactorily.

CHAIRMAN:

Is there any further discussion of the resolution? Are you ready for the question?

AUDIENCE:

Question!

CHAIRMAN:

All in favor of the motion as outlined and moved by Mr. Raoul and seconded by Mr. Jones say "aye".

AUDIENCE:

Aye—Aye—Aye.

CHAIRMAN:

Contrary, the same sign.

AUDIENCE:

No sign.

CHAIRMAN:

The authorization of the resolution has been by unanimous vote. The chairman of the Resolutions Committee, to which are additionally appointed Mr. Harrison Raoul (Belle Glade), Mr. J. C. Stephens (West Palm Beach), and Mr. R. Y. Patterson (Clewiston), will gather his committee and prepare such a resolution as has been discussed here this evening. They will decide to whom it is to be addressed and to whom it is to be sent, the latter not to be accomplished until it has been published in the Proceedings of the Society which will be in Volume XI. All of this is within the convention of the Society's procedure in a matter of this nature.

LUTHER JONES:

This we shall be glad to do.

CHAIRMAN:

If there are no other questions relating back to the evening's discussion I will now turn the Chair back to Vice-President Wander who, I believe, will want to hold a very brief business meeting.

DR. WANDER:

A brief business meeting will be held immediately following the adjournment of the present discussion. It, too, will be an open meeting and all are welcome to stay who are interested in doing so. It will not be recorded. Before adjourning the present meeting I want to add my thanks to all who have taken part in this really interesting and important discussion of Soil and Water Conservation. The Panel Discussion is adjourned herewith. 10:45 P.M.

SYMPOSIUM: AGRONOMIC PHASES OF FIBER CROP PRODUCTION IN SOUTH FLORIDA

THE WORLD CRISIS IN OUR SOFT FIBER SUPPLY*

WALTER R. GUTHRIE **

I'm not used to making speeches, though this talk I'm going to give you this morning is not what you would exactly call a speech but just some remarks of a hard-boiled manufacturer. We try to deal in facts and we are usually pretty conservative in our thinking, though we have had quite a bit of experience with kenaf, that is, with the kenaf that so far has been available. With the thought that some of you folks might be interested in seeing a few of the finished products that we have put kenaf into, if you will come forward at the close of this meeting I shall be glad to show you these yarns and burlaps or I might pass them through the audience at that time so long as we get them back.

The United States Government became interested in kenaf back in 1941 and 1942 when the Japanese were invading the southern part of Asia and, for some time, the Japanese Navy was actually in control of the Bay of Bengal. At that time it looked very much as though the supply of soft fibers from the Far East was going to be shut off completely. Our government therefore became very much interested in a fiber that could take the place of jute at a time when they didn't know how long they would be without this important fiber if the above took place. So the United States Department of Agriculture started to investigate different kinds of fiber and finally decided that kenaf was the most suitable one to do the same kind of a job that jute had been doing. Now I don't know just what the thinking was on the part of the U. S. Department of Agriculture but they decided that kenaf was it. They thought that kenaf was most suitable for introduction into the western hemisphere. And from what I have been able to observe I think they chose very wisely. As a matter of fact, as one who has to use the raw material, I think they did a good job in deciding that kenaf is what they should push. And so, my interest in kenaf actually began when the United States government decided that kenaf had possibilities for the western hemisphere.

About that time they asked me to represent our industry on the Munitions Board. As you probably know, the Munitions Board is located in Washington, with headquarters in the Pentagon, and on that Board there are several sub-committees: a sub-committee for steel, for cotton, for electrical apparatus, and a number of others. One of those sub-committees is the one on fibers of which I am a member. And this sub-committee on fibers decided that it should investigate kenaf, the introduction and use of kenaf very thoroughly.

As a member of this sub-committee of the Munitions Board I took a trip to Florida and Cuba last fall, about a year ago this time. There I saw kenaf that seemed to me was growing very well indeed as far as

* This is a transcript of the purely extemporaneous discussion with which Mr. Guthrie opened the symposium.

** Vice President, The Lehigh Spinning Company, Allentown, Pa.

the production of the plant was concerned. I was pretty well satisfied that kenaf was suitable for Florida and certainly suitable for Cuba and some of the other off-shore countries in the Caribbean.

However, I came to a conclusion last fall that most of my competitors did not agree with me on, at that time, but I think since they have all pretty much come around to think the same way I do about it. I've decided that if kenaf is going to be practicable in the Western hemisphere that we had to get away from retting. In Pakistan, and India, where jute comes from, the production of the fiber is really a peasant industry, that is, each farmer will grow two or three or four acres and he is responsible for retting just this small quantity and that will really be his cash crop. He sells that jute for cash and in many cases that is the only cash income that peasant farmer has. The rest of his land is planted in rice and vegetables and one thing and another so that the development of this fiber production in Asia has been definitely along the lines of a peasant industry. Well, I was satisfied that if we were going to produce a fiber to replace jute in the western hemisphere it couldn't be done on such a peasant industry basis; in fact, it couldn't be done on a retting basis at all. So I advocated at that time that we look very closely into methods of extracting the fiber from the plant on a mechanical basis, either on a mechanical or chemical basis. In any event on some other basis than natural retting as is being done with jute in India.

I presume that most of you gentlemen know what I mean by retting. For the benefit of those who perhaps don't know what retting is, I can only say that you might call it rotting in a certain sense. That is, the stalks are cut down and put in tanks, in rivers or in overflow areas and allowed to remain immersed for from five to ten days depending upon the temperature of the water; sometimes longer. During this time a complex biological action takes place during which the micro-organisms in the water attack the imbedded gums in the fiber, soften them and make it possible to free the fiber from the layers of bark and wood. Because of all the hand labor involved in such a procedure I was quite sure, so far as the Western Hemisphere is concerned that retting was impractical. There just isn't enough cheap labor in this section of the world to ret fiber in this fashion as the cost of the method, under such conditions, would be tremendous. Likewise the lack of knowledge and skill in this sort of work on the part of the people in our part of the world would also prevent it from being a practical procedure for some time to come.

A year ago this time when I advocated that if we were to lick this problem it had to be done on the basis of devising a machine of some kind to extract the fiber from the stalk, I had many critics who thought that the finished product from kenaf would not be of sufficient quality to compete with jute. Well, I have some products here today, gentlemen, finished products, yarn, a carpet over there with kenaf backing, some rope, some burlap cloth. All of this has been made from mechanically decorticated kenaf. So the argument that we cannot apply mechanical decortication to the extraction of fiber from this plant is no longer a good one. For as you see it is now a fact that we can extract the fiber from the stalk and do it mechanically. However, there obviously is still some work to be done on this process. There are different ways of doing this job mechanically and I think we ought to have just as much competition in this as we possibly can because if we have competing studies and

methods of extracting this fiber from the stalk then the "best" method. for obvious reasons, is going to come out much more quickly than would otherwise be the case. It is probable that you people who go on the field trip tomorrow are going to see some kenaf fiber being extracted mechanically out at Belle Glade. This would be a very interesting experience for everyone who is interested in this crop.

After I made the statement last fall in Havana that I was pretty sure that this job could be licked if the fiber could be extracted mechanically one of the big sugar companies in Cuba asked me if my company would be willing to act as consultant for them on this matter of developing a mechanical method of extracting fiber from kenaf; and we have been acting in that capacity ever since. But that doesn't necessarily mean that what we've done and what we are going to do is going to be restricted to them alone. This kenaf business is too big for any one company or one individual to try to control. I'm very sure of that. And I am as satisfied today that we are going to work out the most economical and the best methods of extracting this fiber from the stalk in which it is grown.

However. what I want to talk to you folks about today, principally, is what kenaf is worth, because I think a lot of people are under a false impression right in this connection. As many of you know, the United States Government has a big kenaf seed production program under way at the present time. They have contracted with growers here in Florida and in Cuba to grow kenaf seed and it looks as though by the end of this year Uncle Sam is going to own something like 4 to 5 million pounds of this commodity so that there is going to be an abundant supply for the 1952 season. At the same time the U. S. Government also has offered growers contracts to pay as much as 30 cents per pound for any kenaf fiber that can be produced for them this year.

Now perhaps that's all right at the start. It gives the grower for this first year some incentive. They ought to do all right at 30 cents per pound but I want to discuss this point with you just a little bit. If you are really going to develop a kenaf industry in the Western Hemisphere, we've got to be able to market the fiber for a whole lot less than 30 cents a pound. In the final analysis its John Q. Public that decides what a thing is worth when the finished product is ready for the market. That is to say John Q. Public will be willing to pay a certain price for those products and that more or less determines what an article is worth. In other words, John Q. Public isn't going to pay a disproportionate amount to support a price of 30 cents a pound.

We are beginning to know a lot more about what our cost should be and I want to put my emphasis on that today because if you gentlemen can really get your costs down, and I think you can get them down, a tremendous market for kenaf can be developed in this country. This, of course, can only be if you gentlemen will be satisfied with a reasonable profit per acre and realize at all times that you've got competition, and you are going to continue to have competition from Pakistan and India, chiefly from Pakistan. You are also going to have competition from the paper people in the U. S. A. as they have done a marvelous job of introducing the use of paper for a lot of purposes where jute has previously been used.

The principal product that I manufacture is a jute yarn for the carpet industry. That yarn goes into the back of rugs, wool-faced rugs, rayon-

faced rugs—in fact in the back of most domestic carpet. As a result of recent trials we are finding that kenaf does make a very very excellent carpet yarn. I have a carpet here with a backing made out of kenaf that I would be very happy to show any of you who may be interested.

However, the big market where kenaf could be used in this country is in bags. The bag industry in the United States is a tremendous user today, or was a tremendous user of jute, but jute has been losing out in that field chiefly because it is so expensive. As a matter of fact cotton bags of a lighter construction are being widely used today where jute bags were formerly used. And the use of paper bags, laminated paper bags, as each of you know, has developed rapidly during the past few years for the same reason. Now all that tremendous field can be obtained for the use of kenaf if you gentlemen can see fit to mechanize your operations to get your costs down in a way that will still permit you to make a good profit.

Now I'm not saying you gentlemen shouldn't have a good profit. You should have a good profit because no business is any good unless everybody connected with the transaction is making a reasonable profit. Gentlemen, if you're willing to keep your profit down, if you're willing to say that seventy-five dollars an acre is a fair profit to make after all expenses are paid, and I think seventy-five dollars an acre is a pretty fair profit for you Florida farmers, if you're willing to say a seventy-five dollar an acre profit is acceptable to you and you're willing to get into production on that basis then I'm sure that there is a tremendous field available for kenaf.

It begins to look now, and I think this estimate is pretty generally accepted, that an acre of kenaf can produce about two thousand pounds of fiber. I think an acre of kenaf will easily produce two thousand pounds of fiber and I've heard since I've been down in Florida a day or two of the possibility of very much higher yields on the organic soils out in the Glades.

Well, now, it would seem about fifty dollars an acre ought to be a fair figure for preparing that land and seeding it. Most of you know what that operation is out there. You plow and harrow it to prepare the seedbed and then plant your kenaf with the grain drill or a rice drill. I've been talking with some farmers down here and they seem to think about fifty dollars an acre is a pretty fair figure for the cost of preparing the land and planting the kenaf. Well, on the basis of two thousand pounds per acre of finished product that only amounts to about 2½ cents per pound.

After the kenaf is grown of course it has to be harvested. And it looks now as though the most practical method is to convert those kenaf stalks into ribbons as close to the place where the kenaf was grown as possible. We now have some pretty good ideas of what that is going to cost. We think that it is going to cost well under a cent a pound to do that but let's put down a cent for the cost of ribboning. We're pretty sure it will be done for much less but let's be a little generous and put down a cent for ribboning. Well, that brings the cost, so far, up to three and one-half cents. Now we are pretty sure that the actual decorticating is going to be done for well under a cent a pound, that is to say the extraction of the fiber from the ribbon has got to be done for well under

a cent a pound; but let's be considerate and say a cent for fiber extraction. That brings you up to 4½ cents per pound.

Now, the chances are that you are going to eventually end up with mechanical drying in some form to dry this fiber after it comes out of your decorticator, and then you've got to bale it. So we put in another cent for that. Though it is going to be done also for well under a cent a pound, we'll give you the benefit of the doubt and say a cent for that. So it looks to me if, without putting any overhead or depreciation in, that cost is only up to about 5½ cents. Now let's put in about three cents per pound for overhead. I really think, and mind you, gentlemen, I'm not saying you're going to do that this year, but I'll bet you within a year or two, after you get all the rough spots worked out here in Florida that your actual cost for kenaf is not going to be far from 8½ cents a pound.

Now, if you'll be satisfied with a profit of, say seventy-five dollars an acre, which you can't get on most crops in the south, you could afford to sell fiber and make a good profit for about 12¼ cents a pound. Well, gentlemen, if you can do that, you've got some business on your hands, I'm quite sure of that. If you can turn over to the manufacturer who can convert this material into yarn and into cloth and sell it to him for 12¼ cents a pound, the possibilities of building up a tremendous industry based on kenaf are very very good.

So what I want to recommend to you who are interested in the production of this new crop is that you do everything within your power to mechanize this operation. Don't leave any stone unturned to completely mechanize the whole work. Then, rather than undertake to get a monopoly profit on this thing and make a big killing, if you're satisfied with, we'll say a seventy-five dollar per acre profit, I'm sure that we'll see the day come when there will be thousands and thousands of acres of kenaf planted right here in Florida.

Now I would prefer to answer any questions which any of you may have with which I may be able to help you. However, I'm going to close the more or less formal part of this talk by showing you some of the finished products what we have made out of the mechanically decorticated kenaf which we have been discussing.

* * * * *

First, in regard to this sample of Axminster carpet, about half the weight of this item is kenaf. My customers who buy yarn from me from which to make carpets, say kenaf yarn of this type is very, very satisfactory for this purpose.

I say the cheaper you can get jute or kenaf the more you can sell. In this field today, unfortunately, they are beginning to use a lot of paper in carpet. I don't know whether the women in the audience realize it or not but there are now being made an awful lot of carpets with paper backing. Paper in this form sells for 7½ cents under jute. Jute today sells for about 31 cents a pound, the finished yarn, that is. The manufacturer's cost of the finished yarn is approximately 7 to 12 cents per pound depending on the size of yarn you are talking about.

* * * * *

I don't want anyone to get the impression here today that this sample of rope is better than manila hemp. However, here is a rope for good

general service purposes. As a farm rope, kenaf makes a very excellent product in this field.

Now one of the properties that mechanically decorticated kenaf has which we have not known anything about until a short while ago is mildew resistance, that is, without any treatment. It's much more resistant to mildew than jute. In fact it is more resistant to mildew than untreated cotton. Thus it has this and some other porperties that we didn't expect to find. Therefore, I want to take this opportunity to repeat that if you can get the kenaf cost down to where it should be, and still make a good profit, then there would undoubtedly be a good market for something like this.

Apparently the reason this mechanically decorticated fiber is so resistant to mildew is that in retted fiber the micro-organisms in the retting water stay on in that fiber after it has dried. Then, when you introduce the fiber to a moist, warm exposure again these organisms go back to work on the fiber and continue to break it down and even destroy it. In view of the fact you folks really have plenty of mildew in this part of the country, at least during certain times of the year, this should be a pretty useful article in this section.

In answer to a question someone raised just a moment ago regarding the strength of kenaf, I would say that under equivalent conditions of processing, grading, and testing, it should be about the same; at least I wouldn't say at the moment that it is any stronger than jute.

I am particularly anxious to show you this fine sample of sand bag made from kenaf yarn for the Corps of Engineers. This organization is very much interested in this fiber for strategic reasons. The Quartermaster Corps also is very much interested for the same reason. As a result we have a lot of sand bags made out of kenaf now under test to see how they stand up under such natural conditions of exposure.

Here is a skein of yarn such as the bags were made of. We spun this in our plant at Allentown just a few days ago. It is as fine a sample of yarn as can be made out of kenaf, we believe. It wasn't but two or three months ago that we thought kenaf was a little harsh and a little coarser than jute. We didn't think it could be spun down quite as fine as this. We are finding out new things about kenaf every day and it now looks as though we are getting a type of fine jute yarn out of this fiber.

QUESTION FROM AUDIENCE:

Mr. Guthrie, how about the comparative losses in your spinning operations in handling kenaf versus jute.

MR. GUTHRIE:

Inasmuch as we haven't had too much experience with kenaf in spinning thousands of pounds as yet, I don't want to get way out on the end of a limb until we've had more experience with it. However, we believe that in the quantity handling of kenaf fiber we are going to find that the manufacturing losses will be less with decorticated kenaf than they are with retted jute. There is not so much of that river dirt and foreign material of one kind and another in it because it is washed pretty well in the decorticator before it comes out and we start out with a much cleaner fiber than we do in the case of jute.

QUESTION:

Does it have to be sized: that is, for making rugs?

ANSWER:

The matter of sizing will largely depend on the type of rug you are making. If you are going to use it for velvet loom—for a back on a velvet loom you would probably size it. However, if you were going to use it for the filling of an Axminster loom you wouldn't have to size it. That carpet there (points to sample) is an Axminster type that was not sized. However, latex was put on the back of it after it was manufactured to prevent it from slipping on a polished floor.

QUESTION:

What is the principle source of kenaf fiber at the present time?

ANSWER:

Well, we hope to goodness that one principle place is right here in Florida. We are, of course, really just getting started on this angle of the problem. It looks to be as though the two chief sources of kenaf are going to be Cuba and Florida.

QUESTION:

Can you purchase only limited quantities of it now?

ANSWER:

That is right. Only limited quantities of this fiber are now available. We can import retted kenaf, of course, but I do not want retted kenaf. We want mechanically decorticated kenaf.

QUESTION:

Why?

ANSWER:

Well, it makes a much better product; it makes a superior product.

QUESTION:

Mr. Guthrie, have you checked Puerto Rico as a source of kenaf?

ANSWER:

Yes, Puerto Rico is also a possibility. I understand, however, that land is quite expensive in Puerto Rico. You know that you have some excellent good land down here in Florida for growing kenaf.

QUESTION:

What do the growers feel about $75.00 per acre profit?

ANSWER:

Well, of course, this is a brand new question. I am trying to sell you gentlemen on the idea of keeping your aim down to a reasonable profit per acre and building up volume in this enterprise. If you want to build up a real volume business out of this and are willing to keep that profit at a reasonable level you can surely do it.

QUESTION:

You don't want retted fiber do you?

ANSWER:

No. I'll say. But wait a minute, maybe I had better qualify that statement. If you do a very excellent job of retting, the decorticated fiber wouldn't be any stronger. However, with a retted fiber, you get far more variations. You get some fiber that is very poorly retted and is full of weak spots and you get some other fiber that is very well done and makes an excellent carpet but the average job on a mechanically decorticated fiber will be superior to the average job on retting. Do I make myself understood?

QUESTION:

I would like to know if growers would be willing to accept $75.00 an acre profit? I would like to ask what a grower does get for his crop.

ANSWER:

As mentioned earlier the whole question of production and market is a new one with no one having had very much experience with it. With regard to the "crop" I wonder if you mean your green stuff. While I am not an agriculturist I do like the idea of putting as much of that green material back into the ground as possible.

QUESTION:

How about the decorticating machine that cuts it in the field?

ANSWER:

I think that something could be worked out on that. Of course, this machine that Jack Dempsey has that he is using on ramie will decorticate kenaf. What we are trying to do now is to develop a much cheaper machine that will do as good a job as you can on a big machine. We have been mixed up in the development of a decorticating machine which will be under test in Cuba within 10 days or two weeks and I don't want to say right now that this is the machine but it is a lot closer than anything that I have seen before. What we are trying to develop is a decorticating machine which will sell for less than $5,000 that any farmer can use. It certainly is a fact that an expensive decorticating machine like Jack Dempsey's is a little bit of a stumbling block. We're going all out in getting a machine developed that will be under $5,000 that will do a satisfactory job. I don't want to get into the machine business, what I want is fiber at a reasonable price and it's got to be a mutually profitable deal. It has to be mutually profitable to the grower; it has to be mutually profitable to the manufacturer and in the final analysis, as I have said before, it is John Q. Public that decides what he will pay for things. If you want to make kenaf a luxury business then keep the price way up. However, you're not going to build up any volume. If you want to build volume on kenaf you have to really apply your ingenuity and get your cost down. If you do that I think that you have a marvelous future.

QUESTION:

Is the fiber that is left from a seed crop worth anything?

ANSWER:

It isn't any good for my purposes. However, some manufacturer making a low grade product might be able to use the fiber that is left after the seed crop is removed. I am not going so far as to say that it's not good for anything. It could be used for paper. There is one thing about this particular angle, however, and that is the price for raw material used for paper must be very low. If you get more than 2 or 3 cents per pound for raw material from the paper manufacturer you are doing well.

QUESTION:

Mr. Guthrie, on that paper question, we understand that there is a paper manufacturer in Miami who will pay $300.00 per ton.

ANSWER:

$300.00 a ton? How much is that a pound? Let's see, it's around 15 cents. Well, if you can get anybody to pay 15 cents for it that is swell. It's wonderful. You know, one time I heard a fellow say that you could make $600 00 an acre on kenaf down here. Now, that kind of talk doesn't do this business any good because it sounds too much like a gold mine. If this were true I would get out of the manufacturing business and away from its many headaches and into the business of growing kenaf.

QUESTION:

If you can buy jute for 15 cents a pound, how much will you pay for kenaf?

ANSWER:

I will pay you 15 cents a pound for kenaf. You see, kenaf has some properties that jute doesn't have that can be exploited. This matter of greatly increased resistance to mildew is something that can properly be exploited, if you know what I mean. Good salesmanship could sell a product made out of kenaf, particularly down in the southern part of this country where, at certain times of the year, you are bothered with mildew. In such a situation kenaf mechanically decorticated, could be a very useful product.

QUESTION:

Do you find that there are many grades of kenaf?

ANSWER:

Well, I must tell you that you are a little bit ahead of me. We are going to try to do a little kenaf grading this week right down here in Florida in an effort to set up some tentative grades, some commercial grades of kenaf fiber. I don't believe that there are going to be many grades of kenaf. It strikes me that with mechanical decortication maybe 3 or 4 grades might be sufficient. I can't possibly conceive of how there could be as many different grades of kenaf as there are of jute. However, this classification simply has just got to be developed. We can't have any hard and fast rules to begin with. At least that is my opinion. Are there any other questions?

QUESTION:

What about the cost of manufacturing the yarn?

ANSWER:

It all depends on what size yarn you are talking about. In other words, the finer yarns are more expensive to make than the coarser ones. So we can only talk specifically if you mention a particular kind of yarn.

QUESTION:

What is the relation of fiber grade to manufacturing cost?

ANSWER:

I would say that your manufacturing cost on most low grade fibers wouldn't be any lower; in some cases, it might be a little bit higher. If you are going to spin lower grade products your saving must come from the cost of the fiber. Many times when you try to spin a lower grade fiber you have a higher manufacturing cost because it doesn't run as well.

QUESTION:

What is the cost of a sugar bag and how does the kenaf fiber fit into its production?

ANSWER:

I am not sure. I think about 90 cents. However, I am not thinking about sugar bags. This kenaf fiber is going to have a much higher price and perhaps it is too good for sugar bags. Possibly you could make sugar bags out of some of the poorer grades, I don't know. I do know that the sugar bags made in Calcutta for Cuba today are from very, very low grade jute. Possibly you could make sugar bags out of the fiber from the seed crop that one gentleman was talking about here a while ago. That might be perfectly all right for this purpose. What I am anxious for you gentlemen to do, now we are talking to these growers in Florida, is to make a high quality of kenaf and put it into an equally high quality fabric.

The problem in Cuba regarding the sugar bags is a little bit different. I wasn't thinking in terms of Cuban sugar bags just now. If you could start off with your seed fiber and be willing to sell that for a lower price, maybe 5 or 6 cents a pound, then you could do something with the cheap sugar bag. However, I think the problem in Florida is how to produce a high quality fiber for which you can get the maximum price. Certainly I do not think the problem in Florida is to make a fiber that can be used only in sugar bags.

In concluding and in reply to some remarks that were not too audible I want to emphasize again that my main obective has been to disillusion you people who may need it. You can't make $600.00 an acre on kenaf and make an industry of it.

RAMIE PRODUCTION IN THE FLORIDA EVERGLADES

CHARLES C. SEALE, EDWARD O. GANGSTAD, J. FRANK JOYNER
and JAMES B. PATE *

The fiber plant ramie, *Boehmeria nivea* (L.) Gaud., is of oriental origin and since early times had been grown in many countries of southeastern Asia. The largest area of production is in China, and the fiber is used mainly for making coarse fabrics.

It was not until about the middle of the nineteenth century that ramie became distributed in various parts of Europe, Africa and the Western Hemisphere for the production of fiber.

Ramie was introduced into the United States in 1855 and since that time has been grown experimentally in several of the southern states including Florida, Alabama, Louisiana, Texas and California. In 1943 the growing of ramie was initiated on a commercial scale in Florida. The variety *B. nivea* P. I. 87521 obtained from Japan was used for propagating the crop.

Figure 1.—Ramie observation plots in the fiber plant introduction nursery, Everglades Experiment Station, Belle Glade, Florida.

The plant is a herbaceous perennial and is a member of the Urticaceae or Nettle family. At maturity the stalks are 6 - 7 feet in height and about ½ inch in diameter. The fiber is located in the bast and possesses a high tensile strength, a characteristic that makes it valuable for specialized industrial use.

PRODUCTION AND USE OF FIBER

Under proper conditions of management ramie grows well on the peat soils of the Florida Everglades. However, it is sensitive to flooding and should be grown only where good water control facilities are available. The stand can be severely injured by flooding for 36 to 48 hours.

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Ramie is propagated from rhizome cuttings. Seed is not recommended for planting except for crop improvement through breeding and selection. Planting is done by mechanical methods in the spring or early summer in rows 4 feet apart with plants 1 foot in the row, giving a stand of about 10,000 plants per acre. Planting material loses its viability very rapidly after preparation and should be kept damp and protected from exposure until ready for use.

Figure 2.—Field planting of the commercial variety of ramie, *B. nivea*, P. I. 87521.

Fertilizer is applied at the time of planting in bands between the rows. Subsequent applications are broadcast in the winter season over the standing growth.

Ramie is cultivated mainly for weed control several times after planting until a stand is established. Heavy infestations of broadleaf weeds, which may develop when the stand is reduced by injury from flooding or frost, can be controlled by the use of 2,4-D. The herbicidal treatment temporarily sets back the growth of the plant but does not have a detrimental effect on the quality of the fiber.

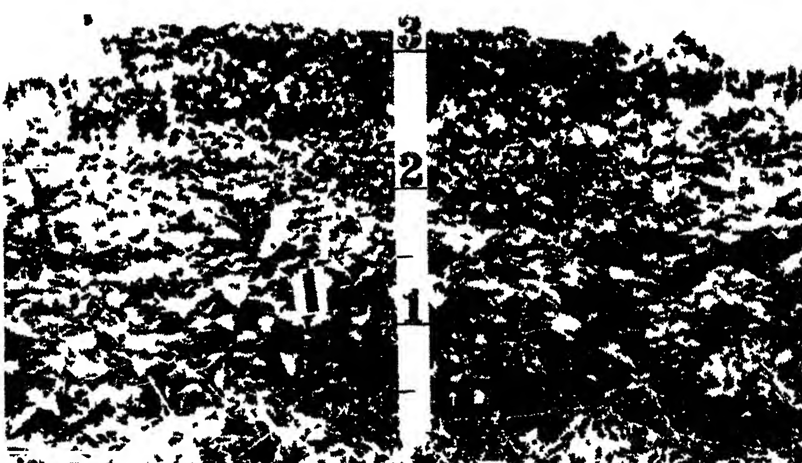

Figure 3.—Very poor growth of ramie in a plot receiving no potash, May 1952, second year of cropping newly cultivated Everglades peat soil, Canal Point, Florida.

The stand is generally ready for harvest the year after planting. The winter growth is cut back or staged in the early spring and three cuttings are generally obtained in a season. The first crop matures in 70 to 80 days. In the summer when conditions of temperature and rainfall are more favorable for growth the second and third crops are ready for harvest in about 60 days. So far no attempt has been made commercially to obtain more than three crops in a season.

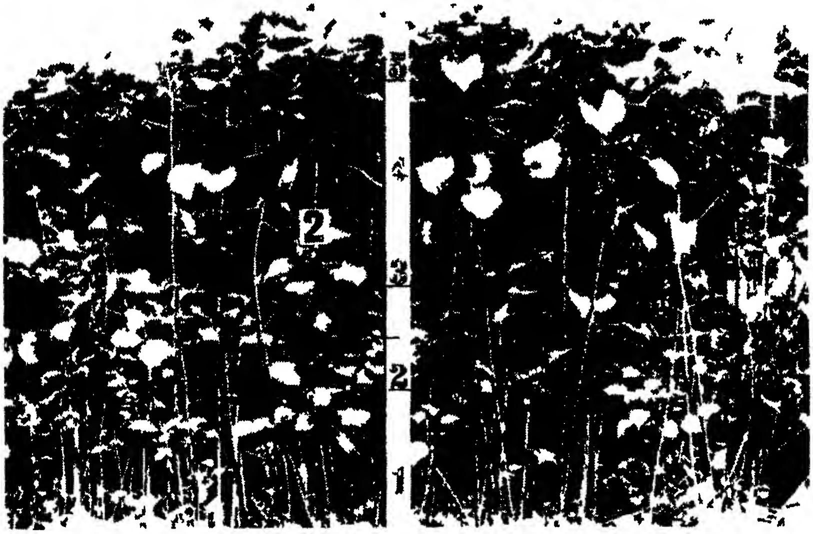

Figure 4.—Normal growth of ramie in a plot receiving an application per acre of 60 pounds P_2O_5, 150 pounds of K_2O and the minor elements copper, manganese, zinc and boron.

After the sixth or seventh year of cropping a decline in yield may occur. In such cases it is generally profitable to rejuvenate growth by deep ploughing and cultivation.

A short time before harvest ramie is defoliated by chemical treatment. The principal benefits of defoliation are (1) an increase in mill capacity and (2) the fertilizer value of the leaves. Recent experimental and large scale commercial test have shown that Endothal (3,6-endoxo-hexahydrophthalate) is effective as a defoliant.

Ramie is harvested, decorticated, dried and baled by modern mechanical methods.

Average yields of total green material and dry decorticated fiber for three crops in a season are 25-30 tons and 1,000-1,800 pounds respectively. In 1952 ramie fiber production in Florida amounted to a little under three million pounds of decorticated fiber from 2,500 acres.

Ramie fiber is used in the manufacture of automobile and furniture upholstery, linen-type fabrics, blends with wool, industrial packing, fire hose, fish nets and other miscellaneous articles.

EXPERIMENTAL STUDIES

A considerable amount of experimental work has been carried out on ramie by the Florida Agricultural Experiment Station in cooperation with the U. S. Department of Agriculture. The more important phases of this work are discussed.

Figure 5.—A close-up view of a ramie plant in bloom.

Since 1945 sixty ramie introductions have been obtained by the Everglades Experiment Station through the Division of Plant Exploration and Introduction of the U. S. Department of Agriculture and through other sources from several foreign countries, including Japan, Philippines, Indonesia, Cuba and Brazil. These introductions have been planted in the fiber nursery at the Everglades Experiment Station and the more promising types have been included in variety experiments.

During 1946-47 crosses were made with four ramie introductions of *B. nivea*, but the seedling obtained were destroyed by flooding. An unsuccessful attempt was made to cross *B. nivea* x *B. cylindrica*. The latter is commonly found growing wild in the Everglades and appears to be tolerant to high soil moisture conditions.

Figure 6.—Root system of ramie showing dense system of rhizomes and storage roots with typical shoot.

In contrast to the limited amount of work done on breeding, a considerable amount of attention has been given to the selection of improved types of ramie which possesses the following characteristics:

(1) a high fiber content of the stalk.
(2) a low green stalk: dry fiber ratio.
(3) a fine denier of fiber.

Some of the most promising selections possessing these characters have been included in variety experiments.

Preliminary trials conducted in 1947-48 indicated that several varieties of ramie *B. nivea* gave very much better yields on Everglades peat soil than on sandy soils in South Florida. Practically all of the varieties tested made very poor growth on Leon fine sand, but a few grew well on Davie mucky sand. More recent variety experiments on Everglades peat soil have shown that an introduction from Brazil *B. nivea* P. I. 205492 Murakami gave a significantly higher yield of fiber than the commercial variety, *B. nivea* P. I. 87521. In these experiments *B. Utilis* P. I. 205502 gave very poor yields.

In fertilizer experiments on newly cultivated Everglades peat soil. the greatest response in the yields of total green material and fiber was obtained from the application of potash and of the minor element zinc. On this type of soil nitrogen and phosphate had no significant effect on yield. On older cultivated Everglades peat soil, which had been cropped for four years with ramie and had received annual applications of potash, phosphate and minor elements, yields were significantly increased by the application of phosphate.

THE CULTURE OF KENAF IN SOUTH FLORIDA

E. O. GANGSTAD, C. C. SEALE, J. B. PATE and J. F. JOYNER *

Kenaf is not a new crop. It has been grown in tropical, subtropical and even temperate climates of the Far East for many centuries. Because hand methods have been required for the culture and processing of the crop, cultivation in the United States has been limited to experimental plantings. However, the potentialities for mechanical production of kenaf fiber have been recognized.

Preliminary trials have shown that the Salvadorian strains of kenaf are well adapted to the conditions of South Florida. Their vegetative vigor is particularly important for high yields of fiber. Manchurian strains ripen early and do not develop well under our conditions and are perhaps more suited to a temperate climate. Various tropical species which have been tested do not give a good yield of fiber. They are generally perennial in growth habit and are to be considered more as ornamentals.

TABLE 1.—RELATION OF PLANT DEVELOPMENT AND KENAF FIBER YIELD TO FOUR DIFFERENT AGES OF GROWTH AT FIVE DIFFERENT DATES OF PLANTING ON EVERGLADES PEAT, 1950 SEASON.

Planting Date	Measurements Taken	Age in Days at Time of Harvest			
		75	100	125	150
15 June	Plant Ht. (In.) *	70	87	115	116
	Stem Dia. (In.) **	8/16	8/16	9/16	10/16
	Fiber Content (%) †	4.41	6.83	6.36	6.33
30 June	Plant Ht. (In.)	73	94	107	111
	Stem Dia. (In.)	8/16	8/16	9/16	9/16
	Fiber Content (%)	5.23	6.31	6.64	6.72
15 July	Plant Ht. (In.)	69	87	96	98
	Stem Dia. (In.)	8/16	9/16	9/16	8/16
	Fiber Content (%)	4.89	5.67	5.46	5.49
30 July	Plant Ht. (In.)	60	68	73	75
	Stem Dia. (In.)	6/16	7/16	7/16	7/16
	Fiber Content (%)	4.05	4.71	4.74	......
15 Aug.	Plant Ht. (In.)	58	62	63	67
	Stem Dia. (In.)	6/16	6/16	6/16	6/16
	Fiber Content (%)	4.16	3.89	4.21	......

* From ground surface to tip.
** As measured at median height of plants.
† Oven dry basis after retting ribbons that had been separated by hand.

The commercial Salvadorian variety has given the best fiber yield, but has several limitations to commercial production. It is susceptible to root knot nematode, root rots and other diseases.

* See footnote page 129.

The Salvadorian strains of kenaf flower and fruit during October. The time of flowering is only slightly affected by date of planting. Vegetative growth is accentuated by planting in the spring, April through June, and a good fiber crop is produced. The vegetative growth of the plant is much reduced by planting in August and September (Table 1), and a smaller plant more readily handled for seed production is obtained. Plantings later than September have not given good yields of seed.

Kenaf is not as limited to a particular soil type or specific soil condition as many crops. In practice, the best seed crops have been obtained on the mineral soils, while the highest yields of fiber have been obtain on the organic soils. It is, in fact, difficult to obtain a good yield of seed on the organic soils. The light sandy soils are not very suitable for seed production because of severe leaching. Applications of fertilizer have in some cases been leached away before the plant has been able to utilize them.

TABLE 2.—Relation of Rate of Kenaf Seeding to Plant Stand and Fiber Yield from a Planting Made April 20, 1950, on Everglades Peat and Harvested at 118 Days of Age (August 16).

Stem Diameter* (Inches)	Plant Height (Inches)	Number of Plants (per A.)	Total Green Weight** (Lbs./A.)	Fiber Content† (Percent)	Fiber Yield (Lbs./A.)
Planted 7 inch row spacing, 10 pounds seed per acre					
¾ - 1¼	99	36,788	29,605	4.24	1,256
½ - ¾	87	32,451	10,144	4.20	431
¼ - ½	69	53,559	4,734	3.66	179
Total		122,307	44,483		1,866
Planted 7 inch row spacing, 20 pounds seed per acre					
¾ - 1¼	105	42,198	36,112	4.39	1,586
½ - ¾	90	37,329	10,956	4.66	510
¼ - ½	75	78,445	6,222	3.99	247
Total		157,972	53,290		2,343
Planted 7 inch row spacing, 70 pounds seed per acre					
¾ - 1¼	111	40,450	34,004	4.48	1,514
½ - ¾	102	61,341	19,225	4.58	873
¼ - ½	78	139,129	10,557	4.10	434
Total		240,920	63,786	-	2,820

* As measured at median height of plant.

** Of entire plant.

† Based on green weight plant material and oven dry fiber after retting ribbons that had been separated by hand.

For good yields, 1,000 to 2,000 pounds of 12-8-8 or 12-8-10 per acre are required on the sandy soils and 500 to 1.000 pounds per acre of 0-8-24 on the new muck soils and a similar amount of 0-8-16 for the older muck soils. The addition of copper is particularly important on the muck soils and has also shown some response on the sandy soils.

The seed may be planted with a standard grain drill using the common seven inch spacing. For fiber, a rate of 25 to 30 pounds per acre on the muck soils has given good results (Table 2). Such a rate of planting

TABLE 3.—RELATION OF DATE OF PLANTING AND OF AGE AT TIME OF HARVEST TO GREEN WEIGHT OF COMPONENT PARTS OF KENAF PLANTS GROWN ON EVERGLADES PEAT, 1950 SEASON.

Planting Date	Plant Component	Age in Days at Time of Harvest			
		75	100	125	150
		Green weight in grams			
15 June	Total Plant	268.0	245.3	490.8	465.6
	Stem	169.7	194.2	404.5	375.6
	Ribbon	69.6	83.5	155.8	150.1
		Percent green weight			
	Leaves	24.4	20.8	17.6	19.3
	Shive	37.4	45.1	50.7	46.4
	Leaves and Shive	61 8	65.9	68.3	67.7
		Green weight in grams			
15 July	Total Plant	222.0	248.2	384.7	325.8
	Stem	150.3	206.0	290.2	269.1
	Ribbon	61.7	84.2	114.2	112.5
		Percent green weight			
	Leaves	32.3	17.0	24.6	17.4
	Shive	39.9	49.1	45.7	48.1
	Leaves and Shive	72.2	66.1	70.3	65.5
		Green weight in grams			
15 Aug.	Total Plant	88.7	112.2	94.3	.....
	Stem	67.5	74.9	76.7	.....
	Ribbon	24.1	28.1	26.8	.....
		Percent green weight			
	Leaves	23.9	33.2	18.7	.....
	Shive	48.9	41.7	52.9	.....
	Leaves and Shive	72.8	74.9	71.6	.....

will generally give 150,000 to 200,000 plants per acre or 4 to 5 plants per square foot. Higher rates of seeding will increase the number of small plants, but the number of plants satisfactory for fiber is not very much increased.

Kenaf should be harvested 100 to 125 days after planting. The percent yield of fiber increases rapidly up to about 100 days maturity. At 125 days the yield is near maximum. After 125 days, the plant soon becomes too mature for easy removal of the fiber, and the quality of the fiber deteriorates.

The best yields of fiber are obtained from the early plantings of kenaf, April through June. The height of the plant, and particularly the diameter of the stem is reduced in the later plantings.

A part of the cost of producing kenaf fiber is due to the large amount of green plant material that must be handled. Defoliation or topping has been advocated to reduce the amount of plant material which would be handled. In experimental plots it was found that the leaves account for 20 to 25 percent of the total green weight (Table 3).

Since the fiber of the kenaf plant is located in the outer portion of the stem, just beneath the bark, it is possible to further reduce the total green weight to be handled by mechanically ribboning the stalk in the field. The shive or inner portion of the stalk is found to account for 40 to 50 percent of the total green weight. If both leaves and shive are removed, 60 to 70 percent of the green weight will be left in the field.

The mechanical harvesting of the kenaf plant is facilitated by the use of topping devices to remove the upper portion of the stalk. Experimental studies (Table 4) have indicated that approximately 6 percent of the total fiber is lost by such a process, if the upper quarter section is removed. The basal portion of the plant contains the most fiber and the fiber yield is critically affected by cutting too high.

TABLE 4.—Total Green Weight in Grams per Section of Plant, the Percent Dry Fiber of Green Stalk Weight and the Percent of Total Fiber in Each Quarter Section, Base to Top, for a June Planting of Salvadorian Kenaf Grown on Everglades Peat, 1950.

Plant Component	Weight of Plant Sections (Grams)*			
	Base ¼ Section	Second ¼ Section	Third ¼ Section	Top ¼ Section
Leaves	.	...	......	88.8
Stalk	136.0	77.9	51.5	26.2
Ribbon	44.4	31.6	18.1	6.8
Fiber**	7.7	5.7	3.1	1.0
Percent Fiber in Section**	6.8	7.4	6.0	3.9
Percent of Total Fiber in Plant**	43.8	32.8	17.7	5.7

* Based on total weight of green plant material.

** Based on oven dry weight of plant material and on oven dry weight of retted fiber from ribbons that had been separated by hand.

THE POTENTIALITIES OF SANSEVIERIA FOR FIBER PRODUCTION IN SOUTH FLORIDA

J. F. JOYNER, J. B. PATE, E. O. GANGSTAD and C. C. SEALE [1]

The more common cordage fibers, abaca, sisal and henequen are imported from the Philippines, East Indies, the Latin Americas and Africa. Although these fibers are standard articles of commerce and are readily obtained in the market during normal times, in the event of national emergency, foreign supplies, especially those from the Eastern Hemisphere, might be drastically reduced and the demand increased. For purposes of strategic defense, we need a plant suitable for hard cordage adapted to large scale mechanized production grown in or near the continental United States. As concluded by a group of specialists during the last war, sansevieria is one of the few hard cordage fiber plants which has potentialities for large scale mechanical production, and may possibly be grown in South Florida.

Original investigation of sansevieria in Florida was made by Dodge in 1892. He noted that the plant grew wild in the southern part of the State, as far north as Lake Worth on the East Coast and the Caloosahatchee River on the West Coast. Wild leaves measuring from 3 to 7 feet in length were obtained from Boca Chica Key and decorticated on a modified Finnegan-Zabrisky machine obtained from Paterson, New Jersey.

Various attempts were made to harvest the wild growth of sansevieria in Africa from 1900 to 1920. European colonists observed that the fiber was a natural resource which might be exploited. Although these attempts appeared successful at first, they were later discontinued at considerable financial loss. The round leaf species growing in these areas had a coarse, poor quality fiber and they did not recover well after cutting. It was soon necessary to go too far afield to gather new material.

From 1910 to 1940, several attempts were made to cultivate sansevieria in Mexico, Cuba, Puerto Rico, the Bahamas and the British West Indies. These efforts have not been very productive. At the present time, a limited amount of sansevieria fiber is produced in Mexico and imported by the United States.

During the last war, the USDA and the Everglades Experiment Station set up a cooperative project at Boynton, Florida, to develop practicable methods for culture, handling, harvesting and processing of sansevieria for fiber production. These investigations were continued after the war and plantings extended to Indiantown in 1950.

In the progress of these studies, it was found that the round leaf species, such as *S. ehrenbergii* Schweinf., the species commonly used for fiber in Africa, were unsuitable for commercial production because of poor fiber quality, slow rate of growth, low yield of fiber per acre and difficulty of reproduction.

The broad coriaceous leaf species such as *S. liberica* Ger. & Labr. and *S. longiflora* Sims have the highest fiber content. However, the fiber is not easily cleaned, the leaves are rather short and they are difficult to

[1] See footnote page 129.

propagate by leaf cuttings. They are, however, readily propagated by rhizomes and tend to have a seasonal growth habit.

The long or petiolar leaf species such as *S. thyrsiflora* Thunb. and *S. trifasciata* Prain, have shown the best promise for fiber production in Florida. They are readily propagated from leaf cuttings which can be planted in a large acreage by mechanical means. Under proper fertilization and adequate supply of moisture, they develop dense stands of plants and a high yield of fiber. While *S. thyrsiflora* has shown considerable damage by frost during the mid-winter season. *S. trifasciata* is somewhat resistant to frost injury. The broader leaf of *S. thyrsiflora* tends to sunburn more than *S. trifasciata*. In a cultivated stand, *S. trifasciata* generally grows somewhat taller and develops a more dense stand. It does not have as high fiber content as *S. thyrsiflora*, but has a higher yield of fiber.

Although sansevieria is commonly thought of as a xerophytic plant, capable of existing under arid conditions, good growth and yield of fiber is not possible without adequate moisture. If moisture supply is not adequate, the plant does not grow.

Proper weed control is also necessary until the stand is established. Weed competition will greatly retard or even prevent the development of a stand. Clean cultivation should be practiced until the plants begin to ratoon. Chemical methods of weed control are being carefully studied and are very promising. A new DuPont experimental weedicide, CMU, has shown very good results in the control of crab grass, water grass and Bermuda grass without injury to the sansevieria.

On the light sandy soils, a relatively high rate of fertilizer is necessary. One thousand pounds per acre of 12-8-8 fertilizer with minor elements and Uramon as a source of nitrogen have given good results. Nitrogen and potash appear to be the most limiting to growth. It also has been found that proper application of N and K increased the resistance of the plants to cold injury.

THE BREEDING OF IMPROVED VARIETIES OF KENAF, SANSEVIERIA AND RAMIE FOR SOUTH FLORIDA

J. B. PATE, J. F. JOYNER, E. O. GANGSTAD and C. C. SEALE *

There has been little research on the improvement of kenaf, sansevieria and ramie through plant breeding. High fiber yield per acre is a character of importance in all three crops. There are also special problems in each crop which can best be solved by breeding.

Variety tests on kenaf, *Hibiscus cannabinus* L., have shown that the Salvadorian strains are best yielding under Florida conditions. However, these strains are susceptible to root-knot nematodes, root rots and other diseases. The development of disease-resistant varieties is the major breeding problem in kenaf.

Several strains of *H. cannabinus* and related *Hibiscus* species were collected and planted in a breeding nursery in 1951 at the Everglades Experiment Station. A severe root-knot nematode infestation and various root rots developed in the nursery. An ornamental *Hibiscus* species was observed to be resistant to the root-knot nematodes and the root rots.

Pure line selection was initiated in the 1951 breeding nursery in the Salvadorian and certain other introductions of kenaf. This method of selection will lead to the development of homogeneous strains of kenaf. In the process of selection, particular attention will be given to disease resistance, plant type, fiber yield and quality of fiber. Crossing of various types of kenaf has already begun. Selection in segregating generations will give combinations of desirable characters present in the two original parents.

Several species of sansevieria have been used for fiber in various parts of the world. These species show variation in ease of propagation by leaf cuttings, rate of growth, length of leaves, resistance to cold injury, recovery after cutting, percent fiber and quality of fiber. *S. trifasciata* Prain appears to be more desirable for fiber production in South Florida than any of the other species. It can be readily propagated by leaf cuttings and recovers well after harvest. It grows faster than the other species and produces a very dense stand of plants with long leaves giving good yields. Though it can withstand frost injury better than the other species, an even more tolerant variety is desired. Other characters which should receive special attention in a breeding program are percent fiber and rate of growth. A small increase in percent fiber represents a substantial increase in yield per acre. Sansevieria is very slow growing and it may be possible to develop varieties with a faster rate of growth than *S. trifasciata*.

Clonal selection within species, seedling selection in *S. trifasciata* and interspecific crossing are breeding methods being followed in the sansevieria breeding program. Clones of different species, particularly *S. trifasciata*, *S. thyrsiflora* Thunb. (*S. guineensis* Willd.), *S. longiflora* Sims and *S. trifasciata* var. *laurentii* (DeWild.) N. E. Br. are being collected in Florida and obtained through the Division of Plant Exploration

* See footnote page 129.

and Introduction, U. S. Department of Agriculture. Clonal selection in a species which is propagated entirely by asexual means would not be expected to be effective unless somatic mutations have occurred. *S. thyrsiflora* does not produce seed and presumably has been propagated entirely asexually. *S. longiflora* and *S. trifasciata* var. *laurentii* produce very few seed and have probably been propagated mainly by asexual methods. Clonal selection in *S. trifasciata* offers the most promise of obtaining different types since it produces abundant seed. These have undoubtedly been spread by birds and other means. Clones of *S. trifasciata* in different localities may have originated from seed and be different genetically.

Since *S. trifasciata* produces seed, seedling selection offers promise in obtaining a cold resistant high yielding strain. At present, over 200 seedlings of *S. trifasciata* have been space planted in the field.

Interspecific crossing offers the possibility of combining desirable characters of two species. Several interspecific crosses involving *S. trifasciata*, *S. trifasciata* var. *laurentii*, *S. parva* N. E. Br., *S. thyrsiflora*, *S. longiflora*, *S. liberica* Ger. & Labr., *S. cylindrica* Boj. and *S. deserti* N. E. Br. have been made. Hybrids of *S. trifasciata* x *S. trifasciata* var. *laurentii*, *S. trifasciata* x *S. parva*, *S. trifasciata* x *S. liberica* and *S. trifasciata* x *S. deserti* have been obtained. *S. trifasciata*, the best natural species for fiber production in South Florida, has thus been crossed with the most cold tolerant type, *S. trifasciata* var. *laurentii*, and with the high fiber content species, *S. liberica*.

Factors in addition to higher yield which should be considered in a breeding program in ramie, *Boehmeria nivea* Gaud., are better quality fiber, particularly finer denier, and reduction in or elimination of seed production. Volunteer seedlings in a planting of a clone of ramie contribute to stand deterioration and may cause a reduction in the uniformity of quality of the fiber. A program of selection in ramie has been going on for some time at the Everglades Station. Early efforts to cross *Bohmeria cylindrica* (L) SW, a species growing wild in the Everglades, with the commercial variety of ramie, an introduction of *B. nivea*, to obtain plants more tolerant to flooding were unsuccessful. Clones arising from seedlings from the commercial variety of ramie and introduced clones are being evaluated. Some of these show considerable promise.

In addition to seedling selection in various varieties and selection among introduced clones, a method which appears worthy of trial is the production of a hybrid ramie. Inbred lines could be obtained by self-pollination. It will probably be necessary to self for 3 - 4 generations to obtain a reasonable degree of uniformity in the inbred lines. Once these pure lines are obtained, the best ones could be intercrossed and the hybrids tested. The hybrid could be propagated asexually and the vigor of the F_1 maintained.

THE OUTLOOK FOR A PILOT-PLANT SANSEVIERIA PROJECT IN SOUTH FLORIDA

Fred Abbott*

Members of the Soil Science Society of Florida and visitors. I find myself this morning somewhat in the position of the little man who had a vocation as an author and an avocation as a lawyer. He told many delightful little stories when with authors that mostly centered around lawyers; and about lawyers when with authors. He at one time remarked that when he was in the presence of lawyers they considered him an author and when he was with a group of authors they considered him a lawyer. And so it is with my position; when I am in a group of railroad men they think of me as a farmer and when I am with a group of farmers they think of me as a railroad man. In any event, a little review of the history of the sansevieria project in Florida might be in order.[1]

Early in World War II when the Japanese took over the Philippines they also gained possession of the great abaca plantations from which the nations of the world then largely secured their supply of marine cordage. The War Production Board immediately began to search for a substitute fiber and asked the Agricultural Department of the Seaboard to assist. We were familiar with the fiber that is recovered from sansevieria and were of the opinion that it would be a satisfactory substitute for abaca (Manila hemp). A quantity of sansevieria leaves harvested on the lower east coast of Florida from wild growth were sent by boat to Cuba for decortication in the sisal mill of International Harvester Company under our direction and at Seaboard expense. The fiber was returned to the American Manufacturing Company, Brooklyn, New York, who made it into ¾ inch rope and found that it compared very favorably with abaca; and was better than sisal. Sansevieria fiber also was found to be well adapted to the hard fiber machinery in use in America.

In 1942 the War Production Board, as a result of the above investigations initiated the setting up of the Research Laboratory at Boynton, Florida. This was to study the agronomic and mechanical problems of producing and processing sansevieria fiber. This work has been continued thru the years by the U.S.D.A. and the Florida Experiment Station on a gradually increasing scale until now it is felt that sufficient information has been developed to warrant the establishment of a semi-commercial plant.

Sansevieria was brought to the attention of Mr. George I. Dewey of the Bureau of Ships of the U. S. Navy. His reaction was that, in the interest of national security, it is what the navy needs as a source of marine cordage fiber located on the mainland of the U. S. where it would be available at any time and all times and grown where it would not displace food and feed crops. Sansevieria grown in certain areas of the lower east coast of Florida fully meets these requirements. Supplies of Florida-grown sansevieria fiber have been furnished the navy's ropewalk in Charlestown Navy Yard, Boston, Mass., several different times at the

* Agricultural Agent, Seaboard Railroad Company, Savannah, Georgia.

[1] Note: A picture of the crop in the field, the decorticator and the baled fiber is to be found in the photo series covering the field trip beginning on page 175.—Ed.

request of Mr. Dewey. At the conclusion of the last test run of 1,000 pounds Mr. Dewey prepared the necessary specifications for purchase of sansevieria fiber by the U. S. Navy as these tests had satisfactorily proven that sansevieria is a satisfactory alternate for abaca. Furthermore, it has been determined that commercial manufacturers are interested in almost unlimited quantities of this fiber. Thus the need for sansevieria fiber has been established both by advice of the armed services in the interest of national security and by those commercial interests who would like to buy this fiber.

The Navy's request of the Munitions Board for a supply of domestically produced sansevieria fiber has resulted in the issuance of a directive to the Secretary of Agriculture for a fiber plant operation. Such a project operating on a pilot plant scale will permit perfection of all phases of growing, harvesting and decortication on a commercial basis and, at the same time, provide a back-log of material and information that would permit the rapid expansion of the acreage in time of emergency. Both the people of the U. S. Department of Agriculture and the Florida State Experiment Station who have worked with this crop through the years are in accord with this pilot plant program, the establishment of which might mean a new industry both for the State of Florida and the United States and go far in avoiding the recurrence of finding ourselves without the necessary fiber supply for marine cordage as we did in World War II. Thank you.

CHAIRMAN:

Are there any questions?

QUESTION:

Why can we not use the abaca from the project that is being developed in Central America?

MR. ABBOTT:

Particularly because of sea transportation that is necessary in getting it to our manufacturing plants.

QUESTION:

Do we have enough foundation plant material to start such a project?

MR. ABBOTT:

Yes, at least in a small way.

QUESTION:

As you may know, there is quite a lot of it growing in various areas down on the Keys. Would this be useful?

MR. ABBOTT:

They won't necessarily use that variety.

QUESTION:

How about growing the crop on down in Central America—say in Costa Rica?[2]

[2] Unfortunately no one seems to have thought of bringing up the question of growing this fiber in frost-free Mexico with her joint boundary line of many hundreds of miles with the U. S. and where there are vast areas of eminently satisfactory land for the purpose. This of course should not minimize the need for working out the problems of mechanized harvesting and processing which, along with higher fiber yields per acre or per hectare, might give this fiber an appreciable advantage over abaca—at least within the field of its particular adaptability. Incidentally, the culture of sansevieria on a small scale has been under way for a number of years in Mexico.—Ed.

MR. ABBOTT:

Doctor (J. J. Ochse), that is what we were talking about. In World War II we wouldn't trust coastwise shipping to get fiber over here as we had 10 to 20 boats a week sunk off the coast of Florida. The Navy wants to get production started in this country. It is true they are developing abaca in Central America and if we could get it here with assurance at all times it would be that much better. However, as I see it we must face the facts and develop a backlog of domestic hard fiber production just as soon as possible.

CHAIRMAN:

Are there any other questions? . . . If not I would like to ask Mr. James M. Dempsey, Manager, Fiber Division, Newport Industries, Inc., if he will lead the discussion.

MR. DEMPSEY:

I was very much impressed by some of the points which were brought out by Mr. Seale and would like to comment on a few of them.[3] First of all is the question of pest control. One kind of insect that we have not been able to control very well is the wire worms that attack the roots of the young plantings. That is one problem which is in need of a little more work.

In my opinion, the work that has been done on fertilization has been most thorough during the past several years. However, the problem of rehabilitation of old plantings is one concerning which we don't know too much. We have done a little work on it and it has been encouraging so far but that is another problem which very definitely must have more work done on it. I know it's pretty close to lunch time but I'll be very glad to do what ever I can with any questions that you may want to raise. However, it would seem that most of the questions on kenaf have already been pretty well covered by Mr. Guthrie and others.

MR. EDWARDS:

I would like to make a remark or two about the various fiber crops being worked on in this area. We have heard a lot of discussion here about the growing and processing of these crops for fiber. There is one thing that hasn't been touched upon at all and that is the various by-products that can be had from these plants. I have analyzed ramie and found that the plant contains gums, waxes, chlorophyll and many other components of potential value if they could be recovered economically. For instance the woody stem is 85 percent pure cellulose which could be used in plastics and in many other ways. In my opinion the by-products of some of our fiber plants could be made to more than pay the whole cost of production. It seems to me that the time has now arrived when we should pay some attention to at least some of the many by-products that could be recovered during the processing of these plants.

MR. DEMPSEY:

From the standpoint of by-products that may be derived from ramie my company hasn't been exactly idle. However, the emphasis very definitely has been put on the recovery of the fiber. It is quite true that there is considerable work that should be done on recovery of other products. In fact, some years ago, when we first started our operations, we started in dehydrating and making a leaf-meal from the tops as was referred to by Mr. Seale. For several years we sold that meal primarily for the extraction of chlorophyll; also as a feed. Insofar as the economics of the operation was concerned, we ran into the problem of high moistures that had to be taken out of the plant. When we finished it was not too profitable because the end product which we sold had to compete with alfalfa leaf-meal; and we also learned that by defoliating in the field before harvesting we could leave about 40 percent of the total green weight of the plant material in the field. This not only added to the nutrient substance, in the form of this crude plant material that it was possible and desirable to leave in the field, but it also gave us an entirely new outlook in the decortication process in view of the greatly reduced amount of plant material that it was necessary to put thru the plant. There are, of course, possi-

[3] Note: Many of the field and mechanical problems referred to in the earlier papers and in the discussion that follows are to be found quite well illustrated in the photo series covering the field trip beginning on page 175.—Ed.

bilities of utilizing the woody material or shives after decortication. However, the best use we know for it at the present is as a compost which when well decomposed makes quite a good organic fertilizer analyzing somewhere in the neighborhood of 4 percent nitrogen, 2 percent phosphate and 2 percent potash. It is especially good as an organic nitrogen for sandy soils. On the peat soil such as we have I don't think that it would be particularly helpful.

QUESTION:

What is the principal use of ramie at the present time?

MR. DEMPSEY:

Prior to 1951 our fiber was largely sold for export where it was used in quite a diversified number of fabrics such as table cloths, towels, sheets; also sewing threads and many other items. It was largely sold to France, Switzerland, Germany and Italy. It also was used in such industrial fabrics as canvas, fire hose, etc. It also was blended with wool in quite an effective manner or was spun by itself for knitting yarns, etc. Those were some of the principal uses before this year. We have since put in a degumming plant which is now in operation. A goodly portion of our production is going to be used domestically from now on. We hope that more and more of it each year will go into a number of diversified products. So far, however, it has largely gone into industrial types of material such as have already been mentioned.

QUESTION:

Does ramie blend well with other fibers?

ANSWER:

It seems to blend with other fibers very effectively. It has certain characteristics that are unique. Particularly in the case of blending with wool it not only adds to the strength of the finished yarn or fabric but also substantially reduces stretch and shrinkage for which all wollen materials are quite well known. We now so definitely believe ramie will be able to find its own place that I would not like to compare it with other fibers or fabrics because of certain characteristics which it has that makes it most unique in a wide field of adaptability.

QUESTION:

Are there many different varieties of ramie and in what way do they vary?

ANSWER:

I believe that most of those types mentioned by Mr. Seale were primarily from seedlings, were they not?

MR. SEALE:

That is correct. We have received for study thru the Division of Plant Exploration and Introduction in Washington small lots of true seeds from a total of 12 varieties of ramie from Indonesia (Java) from which many of them were developed.

MR. DEMPSEY:

We received cuttings of three varieties of ramie that came in at about the same time. These were: Poejong, class 1; Djawa Timoer; and Lembang. Unfortunately the first one germinated only very poorly and we lost it. Insofar as the other two types are concerned, our observation on the peat soils are that the plants do not grow as tall as our standard variety and we have not found that they have a fiber content that is anything to become excited about. However, some of the seedlings that Mr. Seale has been working with certainly show some promise from a selection standpoint.

MR. SEALE:

In addition to the materials from Indonesia already referred to we also have received cuttings of 8 or 9 varieties from the Philippines, some from Brazil and Mexico and two quite interesting types from Japan, namely Saikeiseishin and Kagasei. These latter two, of course, were particularly to assist in our search for a variety with a finer denier than that we now have in general culture.

QUESTION:

What is the principle problem of maintenance in a perennial crop of this nature in its handling from year to year?

MR. DEMPSEY:

The growth of the crop definitely declines as the planting grows older. However, we have only observed seven complete years of growth on peat soils. Generally speaking, after the third year, there is a decline in height of the plant. The roots become more matted, the old plants die off and new ones came along. The stalks also are generally smaller in diameter. Surprisingly enough, however, after the third year, it seems that the stems become easier to decorticate and consequently the fiber recovery is greater. Unfortunately, however, the plants of these older stands seem to have less vitality, consequently if you have a cold winter, like we had last year, there is a tendency towards the production of an inferior first cutting due to losses from the cold and the time required to reestablish the stand.

QUESTION:

Have you tried to rejuvenate an old field?

MR. DEMPSEY:

We studied several methods on a small scale before we decided to try a rehabilitation job on 300 acres. That planting was six years of age and was done last fall. It consisted first of turning the soil fairly deep with a plow, disking, and then leveling. Unfortunately that was done late in the year and we had a number of frosts at the most inopportune times during the winter that followed. Every time the new sprouts would come up they would be knocked down again by the cold. Consequently, we had a very poor first crop. However, the second cutting was quite comparable to a new planting, that is, when you have large, tall stalks that are harder to decorticate and somewhat lower in fiber yield. Unfortunately that was some of the last of our third harvest this year so it will be too late to harvest it a third time. As you can see we don't know too much about the rehabilitation of aging ramie plantings at this time.

QUESTION:

Are there any processors in the United States using your fiber at the present time?

MR. DEMPSEY:

Yes, there are several. Those buying our fiber in any quantity at the present time are using it largely for upholstery and other durable fabrics of this nature. This is as blends for the most part, however, because our limited production wouldn't warrant making up too much yardage of cloth from 100 percent ramie. Furthermore, we have other markets such as are to be found in the packing industries (as in stern tubes on ships) and numerous other novel uses for which we also want to reserve some tonnage. Our domestic market wants only degummed fiber. This, of course, is quite the opposite of the foreign mills. They apparently want to degum the fiber to their own specifications for the type of spinning they use it for.

CHAIRMAN:

Are there any other questions? . . . If not I should like to ask that you return promptly for the afternoon meeting which is to take up the engineering phases of the fiber work beginning promptly at 1:30 o'clock. The meeting is adjourned.

SYMPOSIUM: MECHANICAL AND CHEMICAL ENGINEERING PHASES OF FIBER CROP HARVESTING AND PROCESSING IN SOUTH FLORIDA

A PICTORIAL REVIEW OF PROGRESS OF THE ENGINEERING PHASES TO DATE

MILLS H. BYROM*

I think the talk already given and the discussion that followed have brought out clearly the part that sansevieria may play in the event of another emergency for our armed forces. The other fibers, ramie and kenaf, may be equally important. Before we turn to the pictures, I should like to say a few words about the area that may be affected and something of the effect on the economy of our nation and our particular community if the full scale fiber production industry which we have every right to expect, becomes a reality.

A number of conferences with people in our defense agencies reveal that they are interested in a fiber that might serve for marine cordage in place of abaca. The abaca project in Central America has bolstered our needs to some extent and the Philippines are continually increasing their production, but with all of this, the supply is still far below the need for hard fibers. To make the shortage more critical, the British have severely curtailed the shipment of sisal to this country. Sisal, a cheaper fiber than abaca, meets a definite need in our economy, and with reduced supplies, our manufacturers are sorely in need of something to take its place. They tell us that sansevieria is an excellent alternate for abaca for marine cordage and that it is a superior alternate for sisal. There are a number of products for which sansevieria is particularly well fitted and it will be used in their manufacture as long as it can be obtained in satisfactory quantity and quality. The center core of steel cables is one of these. There are perhaps other. Certainly, once production is started, the fiber will find a niche all its own as Mr. Dempsey was telling us this morning that ramie would do.

The manufacturers and defense agencies who have been consulted, have indicated that they would like to have at least 50 million pounds of sansevieria available on the market in the United States right now. If 2,000 pounds of dry fiber could be raised on an acre it would take 25,000 acres of land to meet the requirements. Even though the fiber situation has materially improved during the years since the war, the improvement has been slow and the situation is still far from satisfactory.

A similar shortage exists with other fibers. We use somthing like 180 million pounds of jute annually in the manufacture of carpet yarns, linoleum backing, insulation for electric wiring, and many other items. Until recently, we have produced no woven goods or bagging from jute in this country. We have taken advantage of the 3 cent labor that is avail-

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able in the Orient and are using it to produce jute fabrics needed rather than to produce them with high priced labor at home. Through the years there has been only one jute weaving mill in the United States. It was located at the Federal prison at San Quinten, California. During a riot at the prison, the mill was burned to the ground, leaving not a single plant that can weave burlap or jute bagging of any kind. I understand from what Mr. Guthrie said this morning that his company has put in a few looms and that others are contemplating the installation of weaving equipment.

Some of the largest users of jute in the United States have told us that regardless of the jute situation in India, they would be glad to use up to half of their total fiber requirements in kenaf produced in the Western Hemisphere in order to establish an industry in this part of the world. We are interested in seeing as much as possible of that industry located in South Florida. Eighty to ninety million pounds of kenaf produced annually would require 50 to 60 thousand acres of land. Kenaf is unlike sansevieria in that it is an annual, grown from seed each year, and since its maturity period is relatively short, 100 days, it can be grown over a wide area in the South. Most of the State Experiment Stations in the Southern states have tried plantings and find that it grows well. We have decorticated samples from several states and find the fiber yield and quality to be good.

The possible needs, present and future, for ramie fiber have been brought out clearly this morning. However, I should like to call attention to the fact that the potential need might mean a much larger demand for fiber than that which can be grown on Everglades soils.

The establishment of a long vegetable fiber industry in this country appears to be confronted with insurmountable problems. The manufacturer cannot tool up his facotory and train workers to fabricate a certain fiber unless he is assured an uninterrupted supply. Likewise the farmer cannot afford to grow it unless he is assured a market at a fair price. At times it appears very difficult to overcome these problems of supply and demand.

The picture we have to show you today is not of any one accomplishment of our research, but is rather a history of the development of fiber processes as they have taken place in South Florida. A great deal of the work on ramie comes from the development of Newport Industries as well as from our own research.

The presentation of the film with a running discussion of its principal features by Mr. Byron followed. Some of the equipment shown in the film, especially the binder and ribboners, including the big decorticator, will be found in the photo series reviewing the field trip beginning on page 175.—Ed.

THE PRESENT NEED FOR A SUITABLE RAMIE AND KENAF HARVESTER AND SOME ADVANTAGES OF LIMITED FIELD PROCESSING

JOHN W. RANDOLPH [*]

Factors now influencing the bast fiber market indicate full justification for the expansion of ramie and kenaf production in Southern Florida and elsewhere in tropical and sub-tropical areas where soil and climatic conditions are suitable. However, trade practices and accepted standards within the textile industry seem to place unusually specific requirements on any material that is offered as an alternate to those that have been in use for many years. This, of course, has particular reference to any effort at substituting kenaf for jute.

Much of the history of bast fibers, insofar as harvesting, processing, and the development of a commercial package is concerned, has been based on hand operations which provided those special skills needed to retain the distinctive qualities of these long fibers. The ultimate arrangement of such fibers in the finest textile products has a close correlation to the pattern worked out by nature in a bast fiber crop where long, undamaged filaments are arranged in a system of true parallelism. For many years some foreign countries have had an abundance of low-cost labor which, under the open market conditions that have prevailed, virtually has given them a monopoly as producers of this type of fiber.

Products of low grade and relatively high cost have been a definite setback to several recent large scale attempts to use available methods of harvesting and processing to build up a new source of supply. This statement should not be accepted as final, however, because these conditions of production have many ramifications in which each seems to have definite opportunities for significant improvement.

The present discussion is limited largely to the harvesting operation especially to the extent it might find a coordinated place in any large scale culture of ramie and kenaf up to the stage of final agricultural processing. A review of past harvester development, a limited examination of the applicable requirements of the textile industry, and an analysis of a bast fiber crop's harvesting problems must all be considered in the development of suitable methods of harvesting for any definite system of processing that is to follow either in the field or in a centralized plant to which, in the latter event, such a great mass of plant material must be transported.

PRESENT SITUATION IN THE HARVESTING OPERATION

The harvesting of ramie and kenaf in South Florida is now carried out with a hybrid John Deere and International hemp binder of war-time vintage. This machine was described in the joint report to the Department of Commerce (1948), "Ramie Production in Florida," as having the following service value:

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"The growing characteristics of ramie present many harvesting problems. The top 12 to 18 inches of plant contain a dense growth of large, hairy leaves which are entwined and tangled before harvest and become more so as the stalks are cut and carried to the tying mechanism. This results in a poorly shaped bundle. To avoid loss in decortication, the bundles must be uniformly butted and the stalks straight and untangled. Due to a combination of plant characteristics and limitations of the machine, a bundle of this quality is not produced. A variation as great as 18 inches in the butting of the stalks is found and many are bent and folded at the tie. Further deterioration in the condition of the bundle takes place each time it is handled in bringing it to the decorticator."

The same report, if it were to cover the kenaf harvesting operations which have entered the field since that time, would have to include an even more drastic series of troubles and to credit the equipment with still larger fiber losses as reflected in both quality and quantity of the final product. Furthermore, if the report were brought up to date in this respect it could give no added improvements in this basic harvester and would have to indicate that the troubles and costs of repairs are actually increasing on this mechanical orphan of World War II.

However, this old hemp binder, as used in the Everglades for the harvesting of these bast fiber crops, is still deserving of much credit because it has helped the development of two large commercial operations. These organizations will give particular credit to their shop and field men who have rendered such excellent mechanical services and have made many modifications to give the machine strength where needed. These men and others have developed many forms of attachments or design changes to improve the work of the binder just as much as possible. The efforts at topping and general improvement in the crop bundle, as produced, were short lived because of the structural and other limitations in the original machine. The bundle carrier designed and built by Newport Industries, Inc., has particular merit because it does a good job, saves much labor, and places no additional load on the binder. This implement, with bundle carrier attached and numerous other mechanical appliances can be seen in the series of photos covering the field trip beginning on page 175.

Chemical defoliation of the ramie crop before harvesting also has many advantages and it is now the accepted practice by Newport Industries, Inc., after having been greatly reduced in cost and increased in effectiveness by many careful trials of rates, materials and timing.

The Importance of Careful Harvesting and Early Handling of Bast Fibers to Insure Favorable Conditions in Which They Arrive at the Mill

Commercial grades for bast fibers include many major considerations in preparation and conditioning in determining these placements. This, in substance, means that all mechanical operations leading up to the final commercial package, the bale, must give the fullest possible consideration to the preservation of maximum parallelism in the fibers as produced by nature. Top values are always received for a full-length

product which has not been subjected to detrimental treatments that have tended to appreciably tangle or alter its natural arrangement.

The need for care and precision in all handling operations involving the raw fiber is well justified by an understanding of the preliminary operations within a spinning mill. It is exceedingly important to understand that any detrimental treatments within a series of mechanical operations that might tend to tangle the fiber can seldom be corrected without increased costs being forced on the successive operations. All fiber abuses will in some way modify the final result. Many practical considerations prevent the development of a continuous series of closely coordinated processing operations between the farm and the fiber industry. Such interruptions take the form of drying, packing, storing, and long distance transportation operations that also can cause disorder and increase the spinning mill's cost.

The "strick", also called "hand", is the true physical unit in the bast fiber exchange between the producer and industry. These small units of fiber, used in the buildup of the commercial bale, are given values on the basis of their quality, preparation, and condition before they were placed in the bale. These values are further modified by the methods used in packing the bale and related conditions.

The spinner desires that each strick will be representative of the whole lot and it should be made up of a fairly uniform quantity of clean, full-length fibers, fully parallel, and evenly butted. There are marked price penalties for tangled lots with matted, criss-cross snarls, nappy fibrous balls, reverse loops, and knots. In fact, a "helter-skelter" arrangement of damaged bast fibers may force a "tow" classification.

The spinner's specifications are in part based on the conditions associated with the buildup of the sliver. This operation, for full length bast fibers, is a slow hand process and it must be carried out with skilled labor. The complexity of the sliver buildup is reduced when each strick in a bale is so packed as to retain its original identity and natural quality. These requirements, translated into action, means that when the strick is correctly opened and grasped by the worker, it can be fanned out by a swing motion into an open, parallel pattern of fiber alignment so that it can be deposited on the "spread board" as required in the completed action obtained with one grasping.

The real art of the sliver buildup is in the maintenance of an exact pattern in adding strick after strick, with the butts in one direction, working out a continuous series of overlaps to anticipate the required density and uniformity of the forthcoming sliver. The spread-board, when loaded with a sliver, serves as the feeder to the first mechanical unit in a spinning mill.

Some mills are quite tolerant as to the amount of plant waste that may be contained in bast fibers. However, they make a major distinction between "free", "embedded", and "firmly attached" wastes. Fibers that have been so processed as to retain much of their natural parallelism and are undamaged otherwise will normally give up "free" waste products in the first operations of a spinning mill. "Imbedded" and "firmly attached" wastes combined with broken and damaged fibers are bound to cause large mill losses.

The somewhat pessimistic facts that have been cited on the primary mechanical processing of bast fiber crops should not be considered dis-

couraging, because they involve relatively recent agricultural introductions of suitable varieties of ramie and kenaf. Instead, one should consider the time and the associated costs required to develop such a complicated machine as an effective cotton picker and many other highly specialized harvesting and processing machines for crops that have been grown on vast acreages in this country from the very start of its colonization.

Stapled Bast Fibers

The ideal requirements essential to the proper farm handling of bast fibers have been minimized by the advocates for stapled ramie fibers which can be used in many textile mills. However, this raw fiber market has it's specific requirements that favor exact uniformity in length of staple without other forms of deterioration. Hence, up to the point of cutting the fibers, all preliminary operations represent no real chance for a compromise in the optimum requirements of harvesting and field processing.

Weight Distribution of Kenaf Crop Among the Component Parts of the Plant with Application to Problems of Harvesting

Gangstad, Seale, Pate, and Joyner in their report on "The Culture of Kenaf in South Florida" which appears in this Proceedings, gave production data for three rates of seeding (Table 2). The average of the three green weight yields reported by these authors has been given a graphic distribution analysis by the use of their sectionalized plant data (Table 4) and other information. Figure 1 shows a graphic weight distribution of leaves and stalks for plants of three different sizes. This height-weight analysis has much significance in connection with methods of harvesting and field ribboning or decortication in which numbers of stalks or size of bundles is used to regulate the operations. As an application of same, let us assume that an in-line field ribboner can handle 4 stalks per unit feeding for the 1¼ to ¾ inch butt diameter group, 7 stalks of the ¾ to ½ group, and 14 stalks ranging from ½ to ¼ inch. Each group will give approximately full coverage over the face of an 18 inch drum. Also let us assume that the feeding and fiber recovery operations (number of men required not part of this report) could be maintained at 20 per minute, the machine's working capacity in terms of pounds of dry fiber per hour is given in Table 1.

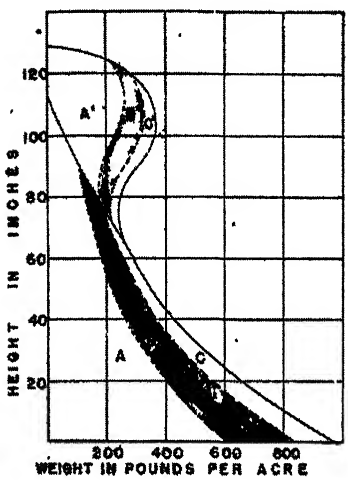
TABLE 1.—Influence of Size of Kenaf Stems on Rate of Ribboning with Hand Fed Machine

Range in Stalk Butt Diameter (In.)	1¼ to ¾	¾ to ½	½ to
Dry Fiber per Hour (Lbs.)	175	116	

Considering the average acre yield as a unit and taking into account feeding adjustments whereby the above assumed rates can be duplicated, it would require 18.9 machine hours to process the fiber from the given acre and the rate of fiber production would be 124 pounds per hour. In actual practice, the overall result might favor discarding the very

smallest canes because the conditions under which they have grown have made the canes soft and tough and clean ribbons cannot be produced from them.

The data shown in Figure 1 has been shifted to a central axis in Figure 2, where the outside outline represents the total makeup of the entire crop on the average acre of kenaf cited above. Attention is called to the fact that the center of gravity of this average crop occurs at 49.97 inches above the base or at about the mid-section elevation. This is important insofar as the action of a reel on a harvester-binder is concrened. In contrast, consider that of a small grain crop where the weight balance is relatively high at crop maturity when a heavy grain head is supported on a light dry straw.



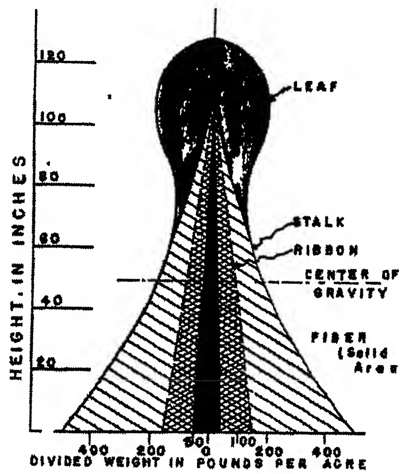


Figure 1 (left). Vertical distribution of green weight in a kenaf crop, leaves and stalks (53,853 lbs. per A.) shown in three stalk sizes ranged as follows: A, ¾ in. to 1¼ in.; B, ¼ in. to ¾ in., and C, ¼ in. to ½ in. (Average of 3 rates of seeding on Everglades peat soil, 1950, as taken from the original data of Gangstad, Seale, Pate and Joyner, this Volume, page 134.

Figure 2 (right). The vertical distribution of the same kenaf yield values displayed in Figure 1 but shown as total leaf and stalk weights and as green ribbon and dry (retted) fiber yields with the center of gravity indicated for the total crop weight (undefoliated)—a value of considerable importance in the harvesting operation.

The reel of a harvester is intended to give the top of each harvested plant a quick backward movement with such timing of action as to force a "free-fall" condition with the hope that all plants will arrive on the platform conveyor in a like pattern. During the harvesting of a matured grain crop, it is a minor problem to adjust a harvester-binder's parts to give a parallel pattern of moving stems or straws that are assembled into a perfectly tied bundle in which all butts are in line. In the instance of kenaf, however, the heavy leaf growth, as well as the frequent tangling of the stems, prevents the development of independent, "free-fall" relationships. Instead, many stalks will slide down over the cutter bar and, by a series of recuts, be greatly reduced in length and, more often than not, initiate "plugging" at that point. The necessity for exaggerating the

action of the reel in an effort to tear apart the tops of plants, combined with other factors. results in the kenaf canes coming to rest on the platform conveyor in a highly tangled condition.

The total crop. as shown in Figures 1 and 2, under most farm conditions, would represent many difficult problems in handling considering only the factors of weight and length of stalks. This, from the standpoint of transportation, regardless of the harvesting procedure, does not fit existing equipment in questions of loading and unloading in ways that will protect the stalks against added tangling and breakage. Fiber crop producers are particularly concerned, therefore, with the development of ways to reduce the heavy tonnage of waste material removed from fields when the central processing plant is used.

The location of a kenaf crop's waste is indicated in Figure 2. The ideal crop harvester would be one that would continue the machine processing action to at least a ribbon stage, so that the minimum amount of waste material will be removed from the field. A less complex harvester might include a topping and a side disposal attachment. Starting at the extreme top of Figue 2, it is evident that different degrees of topping will have only slow increases in the amounts of fiber losses. Table 2, gives the weight of the topped materials that would be removed at different levels.

TABLE 2.—Fiber Losses in Kenaf as Influenced by Height of Topping, Based on Average Yield Data Reported by Gangstad, Seale, Patl, and Joyner.

Height of Topping from Ground (Inches)	Depth of Topping from Top (Inches)	Green Weight in Pounds per Acre				Dry Fiber Losses per Acre	
		Leaves	Stalks	Sub-Total	Percent of Total	Pounds	Percent of Total
117	12	2,891	00	2,891	5.31	.00	.00
111	18	4,955	24	4,979	9.15	.2	—
105	24	6,985	180	7,165	13.17	4.0	.17
99	30	8,820	466	9,286	19.06	12.5	.53
93	36	10,326	901	11,225	20.63	27.5	1.17
87	42	11,100	1,539	12,939	23.78	52.6	2.24
81	48	12,156	2,391	14,517	26.73	90.4	3.86

The above data shows that a twenty-four inch topping would cause a loss of 4 pounds of dry fibers with a field disposal of 7,165 pounds of green material from the tops alone. This 13 percent saving in transportation is significant. The outstanding advantage from the mechanical standpoint is that the harvested material in reduced length is much more convenient to handle with exisiting equipment. One large decorticator in the Belle Glade area can only process stalks under 34 inches in length. The data also shows topping back 48 inches, or to 81 inches above a ground line cutting, gives a field disposal of 12,156 pounds of leaves and 2,391 pounds of green stalks which would represent a loss of 90.4 pounds of fiber per acre. This topping operation as an early part of a harvesting operation in the given example would reduce the maximum length of material 37 percent and tonnage of raw material delivered 27 percent.

The crop losses as influenced by the height of stubble after harvesting are shown in Table 3. It is quite evident that the crop should be cut as low as possible.

TABLE 3. KENAF FIBER LOSSES AS INFLUENCED BY HEIGHT OF STUBBLE BASED ON AVERAGE YIELD DATA REPORTED BY GANGSTAD, SEALE, PATE, AND JOYNER.

Height of Stubble in Inches	Green Weight Not Harvested		Dry Fiber Losses	
	Total Stalks	Percent Total	Weight	Percent Total
12	10,483	19.18	528.1	22.54
10	8,874	16.31	444.5	18.97
8	7,224	13.27	359.1	15.33
6	5,524	10.15	271.8	11.60
4	3,751	6.89	183.0	7.81
2	1,920	3.53	92.5	3.95

Similar data on the weight distribution relationships in the ramie crop are not available. There is little question that its accessibility would help very materially in analyzing some of the harvesting and processing problems associated with this crop, just as in the case of kenaf, even though they may not be nearly as serious in some respects.

Wind Damage

The two fiber crops under discussion develop a dense canopy of leaves on the tender tip of their stalks. Hard rains and variable degrees of wind will cause a few stalks to break over. These, by cross lodging actions, may entwine and tangle the entire crop in a most discouraging manner. Excessive winds and winds in a close cycle rotation forces even greater disorder in such crops. The degree changes in the disorderly condition of the plants in the field will cause ever-increasing operational troubles with the conventional harvester-binder up to the point that the crop has to be abandoned. In many cases the majority of stalks within the zone of maximum fiber production are not damaged.

Requirements of a Bast Crop Harvester

The service requirements for a bast crop harvester would end with an orderly delivery of clean undamaged canes in such patterns of assembly that they can be transferred with maximum economy and efficiency to subsequent processing operations. The qualification "clean" means the removal in the field of reasonable quantities of waste materials consisting of leaves and such parts of the tops as have been damaged by the wind or are in excess of the capacity, as to length, of a decorticator or other machine operations to follow. The requirement "undamaged" canes is most critical to a processing system that uses an automatic grip-conveyor to pick up and to directly transfer the raw material through a series of machine operations.

It has been made evident that the harvester-binder's first operation, the reel's application of force to the tops of a bast fiber crop, fails to produce an orderly movement and assembly of canes. Attention is also called to the fact that a dividing point and a continuous sliding surface

fails to obtain exact swath division and to aid an orderly delivery of cut canes to the platform conveyor. Snarls of rope-like masses that can occur in different zones of a growing bast fiber crop really hold the key to the specifications of the much needed harvester.

The initial harvesting operations must be positive and at a relatively slow speed in the first transitions, which, as further qualifications, must be in exact agreement with the ground travel of the entire unit. The first objective is to have each stalk well supported throughout its length before actual cutting and the starting of the accelerated movements to the point of discharge from the harvester. In case growth conditions or other factors cause stalks to interlock over the line of swath division thereby preventing the positively gripped canes from assuming the machine formed pattern of movement, there should be a supplemental mechanism that, at the proper point and time, would sever any plant part that might tend to prevent the desired action. Subsequently, as the crop is moving through the harvester in a confined pattern, there should be added devices to remove the tops at any level desired and to throw out other undesirable waste materials.

The ultimate design of a really effective harvester for bast fiber crops cannot now be very fully predicted from known facts. It would appear, however, that the corn binder may contain some features of a good basic design for this purpose. Many recent applications of vertical harvesting, as used in Louisiana sugar cane harvesters, also might be subject to further modifications for use in handling ramie and kenaf. The logical summary to this discussion is that the creation of a fully satisfactory harvester for bast-fibered crops represents a problem that should well justify an extensive program of research and development. Certainly it is one that must be solved to at least a reasonable degree before there can be any very considerable expansion of the soft fiber industry in Florida.

PRESENT DEVELOPMENTS IN RIBBONING AND DECORTICATION OF BOTH STEMS AND RIBBONS OF SOFT FIBER PLANTS

H. D. Whittemore and Mills H. Byrom *

We have never given up the idea of combining fibers in much the same way we do grain. The field ribboner is a step in that direction. There have been several private concerns and individuals who have tried machines developed to operate in this way. Thus far, none of these have been accepted as satisfactory. However, there is still hope that eventually the fiber may be taken from the field in a finished form and the rest of the plant material left on the ground where it belongs.[1]

It is desired to emphasize the fact that the "Raspador" decorticator, which is universally condemned for its low efficiency and wastefulness, is the only machine that has been able to produce fiber economically in this country. This type machine will handle ribbons of either ramie or kenaf as well as the stalks of either. The ramie ribbons work a little better in the machine because of the stronger fiber in them.

Mention also should be made of the almost unending stream of new inventions and methods that are coming along. There are more than 2,000 patents on file in the United States Patent Office, most of which claim to be the last word in decorticating ramie or any other long vegetable fiber. In spite of this large number of machines, there is still need for more effective methods of decortication.

We at the Everglades Experiment Station have had the opportunity of examining and trying out a great many of these machines, and find that many of them show some promise. It is evident that more improvements will come in all forms of processing machinery as soon as production of the different fibers can be placed on a commercial basis.

If a long vegetable fiber industry is to be established in the United States, we need the type of cooperation from the manufacturer that Mr. Guthrie has shown this morning. Some of the problems that do not seem to have a solution will be simple if the producer and the spinner can get together. Changes that are not too great may be made in the spinning machinery which will enable the grower to produce a fiber that will bring a profit to him as well as to the manufacturer. It is generally conceded that retting of fiber in this country as is done in the Orient can never be accomplished at a profit to the producer. There is the possibility of mechanizing the handling of water retting processes as well as chemical processes which may produce a fiber of equal quality to water retted material. Either of these processes may be developed to the extent that they will be feasible.

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[1] Most of the conditions and equipment referred to in this discussion will be found quite well illustrated in the photo series covering the field trip beginning on page 175.—Ed.

In 1944, we decoriticated kenaf on the raspador decorticator and sent samples to a number of spinners. The fiber was well cleaned and looked very good for mechanically decorticated material. The response from the American Manufacturing Company in Brooklyn was typical of the others. Their comment was: "we have always spun retted fiber, and while there is a shortage at present, we can still get enough to meet our needs. As long as we can, we will continue to use that type of fiber. As to mechanically decorticated fiber, we can make an excellent product from it, but due to the tooling of our mill and the experience of our operators, we prefer the retted material. The mechanically decorticated fiber contains a certain amount of gums and adhering bark and shives which make it harsh and difficult to work. It is also hard on machinery designed for the softer, retted fiber. For these reasons we will continue to use the retted fiber exclusively as long as it can be obtained."

Most of the spinners seem to object to mechanically decorticated material because of the harsh fibers which are stuck together by gums and strips of bark which are apt to bend or rip the pins out of the carding roll, necessitating a repair job that is expensive and complicated and could possibly stop production of an entire line for several days.

We hope that on the trip tomorrow you will be able to see the ribboning machine at work which was shown in the film. The original model is in the Fiber Laboratory at the Experiment Station. In the fields of the American Kenaf Corporation, however, you will see one or more of these machines (they have built three of them) that have been mounted on airplane type wheels, being pulled through the fields following the harvesting and binding of the crop and operating in that manner.

This machine is designed to produce what we call a ribbon. A ribbon, in the soft fiber business, is that outer part of a stalk that is retained after the woody interior and the leaves have been removed. It may or may not be whole. Usually it is at least partly broken apart along the line of fiber.

The present machine is a development in the Fiber Laboratory at Belle Glade from what was referred to in the movie as a burnishing machine. This latter machine is a single-drum, hand-fed type. In the original burnishing unit the fiber was fed in thru an opening over the top of the drum, pulled out and then turned around and the other end put through and cleaned in the same way. The ribboning machine has two of these drums and uses a continuous series of cast metal pads mounted on chains with spring pressure on them to carry the stalks along, first through one drum which does half of the operation. The grip is then transferred to a second, identical, off-set chain which grips the ribbons produced by the first drum and the partially ribboned stalks are then carried thru a second drum which finishes the job. It may sound a bit complicated when described in this way to people who are not used to some of the machines we work with, but we hope to have you see them tomorrow.

The stationary machine is also useful for other things, primarily for cleaning and straightening dried fiber, the so-called burnishing operation. However, this would be an in-line operation in which you could put the full-length fiber on the feed table perpendicular to it just as in the case of the green stems and take it off in burnished form at the other end. It also could be used in connection with an in-line washing machine for

retted fiber whether the retting was accomplished by natural or chemical means.

As noted before, the machines used by the American Kenaf Corporation are mounted on large-tired wheels and pulled through the field where the bundles are picked up from the ground and spread on a feed table. This operation, of course, follows the binder. It has been pointed out several times that these binders do not make a particularly good bundle. However, the machine that is being developed by Mr. Henriquez has the potentialities of making a nice, clean bundle. If our ribboning machine were to be fed with such bundles, I am sure it would work much more efficiently.

The original intention was to mount the ribboning machine as an attachment on a standard binder of some type which can be drawn through the field. This would cut the crop and feed it directly through the unit. The ribbons would come out the other end and probably thru a double-tie bundling device which should give a bundle that could be carried directly to whatever further processing intended for it. The chief advantage of a field machine of this type would be that it leaves most of the crop waste in the field thus greatly reducing the volume that it would be necessary to transport to and through a processing plant. This, of course, would greatly simplify the waste disposal problem that is ever present where decortication is at a central plant.

After the ribbons are produced there are several methods of processing them. They can be mechanically decorticated as the American Kenaf Corporation is doing at the present time or they can be cleaned either by natural retting or by chemical means. However, we are inclined to agree with the general thinking that natural retting is too slow and expensive.

Chemical treatment for decorticated ribbons has distinct possibilities. Mechanical handling during this process will, of course, be almost essention. As a matter of fact we have gotten quite good results in processing decorticated kenaf fiber by merely boiling in water for a time. The addition of chemicals would naturally cut down on the time but it also would increase the cost somewhat. In the case of processing ribbons it would be necessary for us to make more studies of solutions of several chemicals, detergents or soaps. Under almost any conditions of treatment mechanical action on the fiber seems to be necessary.

THE PROCESSING AND TESTING OF BAST FIBERS FOLLOWING DECORTICATION

T. C. ERWIN*

Following the ribboning or decortication of bast-fibered plants such as ramie or kenaf the ribbons must be degummed and cleaned either by chemical means or by natural retting by way of releasing and preparing the contained fiber for spinning. Most of the earlier work that has been done in this field has been discussed in quite a detailed way in a report to the Department of Commerce (1948)[1] from which the covering summary is quoted as follows:

RESEARCH ON DEGUMMING METHODS

A. *General Principles Involved.* The most significant factors involved in degumming ramie fibers apparently are concentration of caustic, temperature, time and degree of agitation. Possibly the most significant single observation made in all the degumming research is the fact that the degumming solution must be effectively changed in the center of a mass of ramie fiber in order to insure that the gums are rendered uniformly soluble.

The gum content of commercial undegummed fiber (decorticated) has been found to vary from 15 to 35 percent, averaging about 25 percent, and consumes (based on average gum content of 25 percent) from 5 percent to 6 percent of its weight of commercial sodium hydroxide in the degumming procedure.

B. *Pressure Degumming.* Pressure degumming, consuming chemicals at the usual rate, has been found to give a very good product if care is taken during washing and rinsing, following the degumming cook, to prevent excessive tangling.

C. *Open Vat Degumming.* This method of degumming has several advantages over pressure degumming, including lighter and less expensive equipment.

D. *Counter-Flow and In-Line Degumming.* A counter-flow technique is in process of development using large tanks and a centrifuge and has been tested extensively with equipment available in the laboratory. It is believed that eventually the commercially acceptable method of degumming will be based on a system of this type, a continuous operating, counter-flow method. A pilot plant model of this system has been constructed in cooperation with workers in the engineering phase of the report and is undergoing preliminary trials as this report is being written at the close of the project.

E. *Souring and Rinsing.* Experiments have shown that an alkali neutralizing (acidulating) technique can reduce the rinsing time by more than half. Acetic acid has been used extensively for this purpose as no deterioration has been noted in the fiber as a result of contact with even quite highly concentrated solutions or of drying in the fiber, should this occur.

F. *Bleaching.* Ordinarily, this operation probably would be completed after spinning and weaving into fabric, but a number of experiments were conducted to determine the effects of bleaching on degummed fiber. It has been found that degummed fiber can be bleached in a chlorine solution to an acceptable degree of whiteness in less than 15 minutes without any apparent damage to the fiber.

G. *Softening.* Experiments have been conducted with a large number of textile softeners from which a variety of finishes have been obtained. These softeners

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[1] *Ramie Production in Florida*, A Progress Report prepared for the United States Department of Commerce by the United States Department of Agriculture and the Florida Experiment Station at the close of Contract No. Cac-47-6 between the Department of Commerce and The Board of Control of State Institutions (1948).

included soluble oils, cationics and sulfonated tallow. Chemical softening is essential before the fiber can be combed or carded.

H. *Reducing Agents.* It has been found necessary, especially in open vat degumming, to use a reducing agent to prevent damage by sodium hydroxide used in degumming. At this time, sodium sulfite and sodium sulfide are considered satisfactory chemicals for this purpose.

I. *Other Degumming Chemicals and Methods.* Patent literature and other literature on degumming were explored extensively and most of the more promising methods were duplicated as closely as laboratory methods would permit. Numerous chemicals were tested and attempts were made to degum ramie fiber by bacteriological action. A number of the chemicals gave quite satisfactory results if the process is carefully controlled. Some of them would be too expensive under practical conditions of operation. Degumming of ramie by retting has given uniformly poor results.

J. *Detergents.* Various commercial wetting agents and detergents were tested in the degumming baths and in the washing and rinsing steps. Sodium tripolyphosphate has proven quite a satisfactory chemical in both the degumming cooks and in the washing and rinsing baths.

K. *Chemical Degumming of Whole, Pre-Stapled Stalks.* Degumming whole, pre-stapled stalks would give the advantage of an accurate staple length, an important consideration in spinning on the cotton system. One of the unsolved problems connected with this type of degumming is the separation of the wood and the fiber after degumming. Separation was attempted by a number of concerns who manufacture fiber cleaning machinery, but without satisfactory results in any instance.

L. *Degumming Fresh, Undried Ribbon.* Tensile strength has been noted to be somewhat less for fiber degummed in a fresh, wet condition without prior drying. Souring before degumming has been observed to assist in the matter of strength values of the final product when degummed in this way. If this procedure can be considered practical, one drying would be eliminated and it would make possible a complete in-line operation for a centrally located ramie decorticating plant.

In a similar manner the methods used in testing and in studying factors affecting the quality of fiber from several standpoints were discussed in the above referred to report from which the summary also is quoted for the quick picture it gives of this phase of the work as a whole:

FIBER TECHNOLOGICAL STUDIES (TESTING)

A. *Facilities.* A fiber testing laboratory, equipped with an air conditioning unit to maintain a temperature of 70° F. and a relative humidity of 65 percent, has been established and equipped with a Scott Tester Model, DH, a Scott Tester IP-4, a flex testing machine and a wear testing machine, with which it is possible to make the following standard tests: tensile strength, sheer strength, elongation or stretch, flex and wear. Other equipment is available for preparing test samples and studying their weight and density.

B. *Summary of Tests Made.* To date, approximately 550 samples[2] have been tested in this laboratory, including many from private industry and several large series from various phases of the research programs in this project. Normal ramie fiber will test, on the average, about 60,000 pounds per square inch on a half inch break made according to the standard procedure for cordage fibers.

C. *Quality of the Fiber as Affected by: (a) Maturity of the Stalk.* Samples of fiber from the age studies have been tested to determine the fiber quality as affected by the days of growth of the ramie stalks. It has been found that the tensile strength increases rapidly during what is considered the normal maturity period (60 to 70 days) and continues to increase up to about 100 days; also, that flex life decreases rapidly to the maturity point and then levels off. It would appear that most of the variation noted in tensile strength may be due to the state of maturity of the fiber. Microscopic studies of fiber from immature and mature stalks show the young fibers as thin, flat ribbons with large, collapsed lumens while the more mature fibers show a thickening of the fiber wall and a more cylindrical shape.

[2] To date of this meeting the number of samples tested had mounted to nearly 3,000.

(b) *Variety.* Fiber samples from the variety studies have been tested for physical properties and examined microscopically. Certain variations in tensile strength have not been considered significant but more probably an indication of the degree of maturity of the variety at the time of harvest. Microscopic variations also are believed to express differences in maturity, inasmuch as similar differences were noted in the age studies.

(c) *Fertility of the Soil.* Fiber studies also were made to determine physical properties and microscopic characteristics of samples of fiber taken from different treatments of the fertilizer trials. The differences noted in the laboratory were not considered significant. For this reason, it is believed that growth differences noted in the field will give a more definite indication of fertilizer requirements.

(d) *Manner of Decortication.* Comparative tests have been made using fiber from various methods of mechanical decortication to determine to what extent the fiber strength has been affected. It appears that, within reason, the harsher the mechanical treatment, the less fiber is recovered, but that this fiber is of the greater tensile strength due to the loss of weak fibers in decortication.

(e) *Storage and Age of the Fiber.* It has been demonstrated that there is a rather definite increase in the tensile strength of ramie fiber due to drying and aging before degumming when this operation is accomplished by one of the methods now in use at this laboratory. However, there are hazards in drying and storing, such as mildew, which must be considered.

(f) *Method of Degumming.* Good degumming results have been obtained with ramie fiber using both pressure and open vat methods. The results from a large number of tests made in this laboratory indicate that there is no apparent damage to ramie fiber from steam pressures up to 80 pounds per square inch and no obvious damage from sodium hydroxide solutions in concentrations up to 5 percent when used in conjunction with a reducing agent.

D. *Properties of Ramie Fiber:* (a) *Differential Dye Tests and Uniformity of Samples.* A differential dye test, developed by the Southern Regional Research Labortory of the U. S. Department of Agriculture to determine the maturity of cotton, has been applied to several samples of ramie fiber with excellent results. Microscopic examination also showed a good degree of correlation when made of samples taken from the age test studies, between cell form and uptake of dye in relation to maturity.

(b) *Microscopic Studies.* Microscopic studies indicate that standard commercial ramie will have a cross section somewhat similar to cotton in shape, but it will be more regular and larger, averaging approximately 8 denier or 50 microns in diameter. The length of the individual cells varies from 1 to 20 inches, averaging between 5 and 8 inches.

E. *Test Methods:* (a) *Standard Degumming Method for Test Samples.* A standard procedure for degumming samples of ramie fiber to test comparatively in the fiber test laboratory and for the age test series has been outlined. This method uses a pressure cook at 40 pounds per square inch in 5 percent sodium hydroxide solution (based on dry fiber weight) 1 to 1 fiber-water ratio, followed by soap cook and acid sour.

(b) *Fiber Test Methods.* For testing ramie on the long fiber testing equipment, it was necessary to make a crude yarn This yarn, or bundle, was cut to a standard length and weight, attached to cardboard tabs, and allowed to condition at least 24 hours in the test laboratory under standard conditions of temperature and humidity. Complete tests include the following: twenty half inch breaks, twenty three inch breaks, six flex and twenty-four wear samples. It is impractical to test stapled material shorter than two inches, and only tensile strength determinations for ½ inch and 0 inch can be made. Manufactured yarns were tested on the IP-1 machine, which determined three-inch tensile strength.

It is readily understood that the work in the degumming and testing fields must be developed in very close cooperation with that in agronomy and engineering because of the many determining factors and influences that are to be found in both of them.

For the purposes of the present review it might be well to discuss a little further three points in particular concerning this phase of the work, namely:

1. Some of the things we have learned from the testing program.
2. Some of the principles involved in degumming, and
3. Some of the problems it is necessary to overcome in making the fiber ready for the spinner.

Naturally, most attention will be given to ramie as that is the fiber with which most work has been done up to the present time and about which we have learned most as a result of the processing and testing program to date. Such a program is not only one of finding facts for their own sake but also for use in establishing a sound basis for the consideration of this fiber as a commodity of commerce relieved as completely as possible from the imaginative qualities that have been conferred upon it by promoters of various qualifications and intent through the years.

In setting up the testing work we started out with a system which is more or less standard for "hard" fibers. Therefore, since ramie is a "soft" or bast fiber rather than a hard, or leaf fiber, the testing procedures are not too well adapted. We have made some modifications and are coming to feel that we are learning from these methods what steps should be taken to set up a better system for ramie. In this way it is hoped that when the time comes and the culture of ramie has become sufficiently extensive there will have been developed a standard system of testing that is much more applicable than at the present, and one that may be adopted the world over.

One of the first adverse criticisms we have heard about ramie is that it has no flex. On this account it has been reported to be no good in certain uses and just doesn't hold up. In other words, if a fabric is creased repeatedly at the same point, as in pressing clothing, it will break at the crease, and all that sort of thing. In consequence of such rumors we decided to investigate this characteristic of the fiber. The first thing we found out was if you take a section of undegummed ramie fiber, it has practically no flex at all—that it is actually quite brittle. As a matter of fact, you can't even get a good tensile strength test on fibers in such condition unless you go to the individual fiber because you can't load a bunch of such fibers evenly enough when the gums are still set in and around them to give a uniform tension on all fibers of such a group. Consequently, when you try to break them under such conditions you break them more or less one at a time and your test value shows up accordingly. We soon learned, however, that if the fibers were properly cleaned and degummed the flex increased very greatly, especially after proper softening. Be that as it may, we are still not prepared to say that flex is one of its outstanding properties especially when compared to nylon and some of the other synthetics.

We also learned that ramie has quite a variation in flex as among the different samples that were tested and we decided to try to find out why. This question of variability seemed to be satisfactorily answered when we got into the study of microscopic cross sections of the different samples.

Thus by studying how the ramie fiber develops it was found that the outside diameter is established quite early. According to the manner of growth the young fiber continues to be quite flat for some time and with a central opening that also is flattish in shape in contrast to the more

nearly round opening of the more mature fibers. Briefly stated, the flattish, immature fibers that are so apparent in the photomicrograph of a cross-section of the stem of a ramie plant are high in flex but low in tensile strength. The tensile strength of the fiber is therefore known to increase with the changing form and the maturity of the plant whereas the flex decreases.

Inasmuch as the position of the fiber in the individual stem relates quite closely to its maturity and form it is readily understandable that we never harvest the crop with all the fiber in the plant at full maturity or with even a reasonably high flex. Those fibers at the base of the plant are most mature, those in the mid-section intermediate in this respect and those near the top the most immature. Consequently there is an inverse gradient running up and down the plant from base to tip, and vice versa, as to tensile strength of the fibers on the one hand and their ability to take flex, on the other. In consequence of these conditions and the present manner of harvesting and processing the crop, it is readily seen that the general, commercial type of fiber usually will have more or less average or intermediate values with respect to both of these qualities.

Since the position in the stalk has a great deal to do with whether you have one type of fiber or the other with respect to qualities of strength and flex and even fineness, that is one of the things which we may be able to take into consideration in future harvesting and processing operations in relation to grades. Of course the manner in which we are going to separate it and the details of such an effort will depend largely on what the limitations and requirements of the spinner are going to be. On account of these fiber quality variations within the plant there has been quite a lot of discussion as to whether we should separate it into top, middle and butt fibers. While this has not yet been undertaken in any practical way, it is possible that much greater uniformity could be achieved by such a procedure in the ultimate characteristics of the fibers and consequently a much closer and more satisfactory system of grade set up. As a first consideration, since the tops of the stalks have much less fiber in them and the fiber is of a considerably different quality than that of the rest of the plant, it might be a good idea to top the plants somewhat lower than might otherwise be considered practical.

Another characteristic of ramie fiber that we have been hearing a great deal about is the almost complete absence of stretch. In other words it is not an elastic fiber as it is susceptible neither to stretching or shrinking. On this account it is coming to find quite an important place in blends, specially with such a fiber as wool which is all but famous for both stretch and shrink. It is said that as little as 25 percent of ramie incorporated with wool will go far in stabilizing a fabric made from such a blending of fibers.

One of ramie's most conspicuous shortcomings is the almost complete absence in it, under natural conditions, of spirality or twist that is so important in causing fibers to cling together and give maximum strength in yarns made from fibers of more or less minimum length. It is on this account in particular that added emphasis is being given to using this fiber in as great length as a particular system will permit since strength is thus obtained thru length. The same idea holds in the use of the finer

fibers in the spinning of finer and finer yarns for the weaving of the sheerest possible fabrics.

In the degumming of ramie the basis of practically all the processes used the world over is a caustic cook in some form. Most of the gums and other materials that are in ramie fiber are not water soluble and, on this account, if they are to be removed effectively they must be treated with some chemical in order to get them into suspension or solution and thus mobile. Actually, decorticated or ribboned ramie fiber will contain from 15 to 25 and even 35 percent gums, depending upon the decortication or ribboning process used. The cleanest fiber is usually produced with the use of plenty of water on the wheels (in the instance of the large centrally located unit) during the decorticating operation. A considerable part of the embedded plant material is sufficiently soluble or suspendable to be removed in this way. Once the fiber is dry it is very difficult to re-wet; hence, without doubt, the considerable soaking periods that Miss Montgomery told us about yesterday as currently used in the Orient.

It seems that the primary problem in the caustic cook is to get the active chemical to each fiber and then to remove the dissolved or suspended waste materials. When you are removing say 20 percent of the gross weight of a material that is quite a large amount that must be handled in this way. In other words, there is not much point in softening the gums then letting a substantial part of them dry back on the fibers where they were before. Therefore, any mechanical action that can be maintained during the degumming process is important. The Japanese process which you saw on the film shown yesterday has the essential points necessary. The only thing is, of course, just as Miss Montgomery said, if you have plenty of hand labor there is nothing to it.

Actually we believe the most efficient process for our conditions will be based on two general principles. One of them is the counter flow of fiber and solution. In other words, remove the waste from the end of the system at which the raw fiber is introduced and introduce clean solution into the end of the system from which the clean fibers are removed. The other item of particular importance in the effective degumming of fibers in such a system is to have a mechanical process that will keep the liquid which is in contact with the fiber constantly on the move. Squeeze rolls are, of course, quite good. This mechanical action can be offset by *time*, however, since, if given sufficient time, the chemicals will diffuse thru the medium and reach the fibers. Unfortunately this does not make for uniformity of the action of the chemical on the entire mass of the fiber both as to concentration of the chemical and duration of the action. In other words the fibers at the center of a given mass are exposed to the weakest chemical for the shortest time.

I should like now to pass on from the problems of degumming to some of those concerned with the preparation of the fiber for spinning. It is believed the primary problem that has been encountered in the spinning of ramie has been in establishing staple length and selecting the spinning system which will take the staple lengths that can be produced. This, of course, is in relation to the almost complete absence of spirality in any form in this fiber in its natural condition. There is one thing which I think should be pointed out in connection with the process which Miss Montgomery showed you that is being used in Japan. Reference is to

the fact that in their fiber preparation operation they produce three kinds of stock and I don't believe that there has been a system developed anywhere else by which you can produce a fine long stapled fiber and get a recovery of about 30 percent of your total original degummed fiber in this longer staple.

I believe I quote Miss Montgomery correctly on their recovering 30 percent of the long fiber while about 40 percent goes to the wool or intermediate system and another 30 percent back to the cotton system. That is certainly a pretty efficient utilization of your fiber stock. Still if you are talking about the price of your very sheer materials and fancy goods you must remember that you are talking of the top 30 percent of your production. We suspect that the secret of the success of the system you saw in the movie yesterday is that big scissors operation. That is the "know how", in that instance coupled with very low-priced but efficient labor, that has provided an effective system under those conditions.

Under the system in common use in this country, once the fiber has been decorticated and dried, the next step is to get it into the best possible alignment preparatory to stapling. This is usually done by brushing or burnishing in order to remove as much of the retained bark and shive as possible and get out those insidious angles and kinks which are certain, otherwise, to considerably reduce the efficiency of the stapling procedure.

At this point it might be well to mention an idea that apparently has occurred to several people since "pre-stapling" while the fiber is still in the plant stem seems to have been tried by a number of operators during the past few years. In other words, these fibers while still in the plant structure are in perfect alignment and that should be the ideal time to staple or cut them into pre-determined lengths, all other conditions being equal. It really sounds like quite a good idea if a method can be developed for handling the chopped stems from the point of stapling on through.

Of course, all the spinning systems have a certain amount of tolerance as to length of staple they can take. Still another process has been tried by at least one mill that is very similar to the one we saw operating in the movie yesterday except they don't use quite as much hand labor. In this method there is produced some kind of a sliver out of the full length fiber. This is stapled and the process is repeated until the desired fiber length is attained and ready for spinning.

If we can lick this problem of preparing accurate staple lengths we can certainly obtain higher "yields" of the type of yarn that we are setting out to make. Actually the normal array of ramie fiber is quite variable. Therefore, we are going to have to take some loss some place along the line if we want to spin ten-inch staple. That, of course, would be our top quality but there will probably not be a very large percentage available in this staple length. It seems that the present trend is to staple from three to maybe six inches on the long end and to try to get the top quality in that range and then recover the tow from that process and use it on some of the shorter methods for a cheaper type of yarn. Thank you.

CHAIRMAN:

Are there any questions? . . . If not I should like to ask Mr. Whittemore if he has anything to add to the discussion of this phase of fiber handling at this time.

Mr. Whittemore:

About the only comment I would like to add at this time to what has been said is to more or less re-emphasize the importance of age and varietal studies of bast fiber plants in relation to the quality of the fiber that is to be expected at the time of harvest. Reference is, of course, to fineness of the fiber ("denier") as well as strength and other characteristics such as flex.

Chairman:

I would like to ask Mr. Walter R. Guthrie, Vice President of Lehigh Spinning Company of Allentown, Pennsylvania, if he will now open the discussion on this general phase of the subject by telling us something about the work he is doing on the mechanization of kenaf harvesting and processing in Cuba.

Mr. Guthrie:

Mr. Chairman, Ladies and Gentlemen: I suspect that most of you probably heard enough from me this morning. Your Chairman says that I am now to tell you about what is going on in Cuba with regard to the field processing of kenaf. I must first of all tell you there is a lot going on in Cuba that I don't know anything about.

However, I do know something about what one particular producer in Cuba is doing with kenaf; and that is just about the extent of my knowledge of what is going on down there in connection with the development of this crop. Briefly, this Cuban Company asked us to act as a consultant for them in their kenaf program and that is what we have been doing for them this past year.

Having had training in mechanical engineering I try to tackle problems of manufacturing by getting things done on the basis of moving materials about with the least amount of effort. This is because I know definitely in manufacturing, where I have had some experience, that your costs are chiefly built about the cost of moving things around. Actually, running materials through a machine can be done very cheaply. It's the cost of moving them from one spot to another in any manufacturing operation that costs you money. So naturally, when I tackle a job, I try to hold to the greatest practical minimum the amount of effort that is to be expended in this sort of activity.

Consequently when my company took on the job of trying to see what could be done about kenaf for this company in Cuba my first thought was to see how little effort it was necessary to expend in moving things around. So we started with the ribboning of the plants in the field, and what we propose to do is this. We are going to ribbon the plants exactly where they are grown, right there in the field. In this way we are going to get rid of as much of that green material, the waste, as soon as possible for two reasons. The chief reason is we don't want to pay the cost of moving it elsewhere. The second reason is that we would like to leave it right there on the land where it will act as a fertilizer.

Following the ribboning operation we then want to move our ribbons just as short a distance as possible. Naturally we have to move them to a decorticating machine which is semi-portable and which would be located at the nearest source of water. In some cases we are planning on drilling some wells because we think it is a lot cheaper to drill wells than it is to move a heavy tonnage of such material a long distance.

When the fiber comes out of the decorticator, we then propose to move it to a central plant where it will be mechanically dried and baled. The fundamental idea behind the whole process is, then, to move as little tonnage as we possibly can to get the maximum amount of clean dry fiber with a minimum expenditure of energy. Now if we carry through on those fundamental ideas I think we will end up with as low a cost as is possible.

However, when we started with the ribboning machines which were being used in Cuba we first thought they were doing quite a good job. Then we decided that we needed a little different type because we had to end up decorticating that material by mechanical means. And so, in addition to breaking the wood out and getting rid of the foliage we also wanted to get rid of as much of that heavy green material as possible, particularly on the butt ends of the ribbons, so as to lighten the load on the decorticating machine just as much as possible.

While we don't want to tell you too much about this machine, prematurely, when we finally get this operation worked out, and we hope that will be before the end

of November, I am quite sure that the information will be made available to every-one. Although we have designed a machine, in fact this is the third machine we have designed and built, to decorticate kenaf, I can't tell you just where it is at this particular moment—probably somewhere between Allentown, Pa., and Cuba. However, it is our hope that in another week or ten days we will have this unit at work down there. We are going to run it 24 hours a day, 7 days a week as long as there is suitable kenaf in Cuba to put through it. We will then be able to study the results and calculate just exactly what our production is going to be, as well as the costs. This machine may be the answer or it may not be the answer. I am not going to be dogmatic about this thing at all, gentlemen. We are only trying to solve the problem. We are trying to solve it in a little different way than you folks in Florida. In time, you may have the right answer; or we may have the right answer, I don't know. However, what I want is fiber. I don't care whether Florida comes up with the right method or Cuba comes up with the right method, what we all want is a good quality of kenaf fiber produced as economically as it can possibly be done. So that, in general, is what one particular outfit in Cuba is doing.

Now this machine that we think, and hope, is going to be successful, should produce about 600 pounds an hour, theoretically at least, and it is going to take three men to operate it. There will be two men feeding it and one man taking care of the delivery end. So we shall be able to figure out quite simply what it is going to cost to decorticate on that machine. I wouldn't be surprised if we will decorticate for about ¼ cent per pound, that is for labor only with no overhead included. But that, gentlemen, is not as yet a fact. We hope that before the end of November we can say to you that it is a fact.

Mr. Chairman, I don't know whether there is anything else that I should add. There are several new faces in the audience this afternoon in comparison to the morning meeting. I wish that we could again, just very hurriedly, show them your rug here.

CHAIRMAN:

Go ahead, but remember, I promised to give this rug to Mrs. Allison, who so assiduously has been relieving our good members, old and new, of their dues all thru the day at the registration desk. Please don't let anybody run away with it.

MR. GUTHRIE:

I prefer to guarantee nothing on that score after what happened to my kenaf sand bag this morning. However, we have here a finished product, an Axminster rug that is made out of kenaf yarn. About 50 percent of the weight of this rug is kenaf and I think you will agree if you examine it carefully that this fiber does make a very beautiful yarn. And it so happens that about 130-140 million pounds of such yarn is used in fabrics of this kind in this country every year. So you see there is a very good potential market for kenaf yarn right there.

I should like also to again show you this kenaf rope and a few other items made from this very acceptable substitute for jute. Now I am not saying that this is as good a rope as if made from sansevieria. Please don't get me wrong, but for a cheaper farm rope that is very strong and very useful it could be developed into a product of considerable fiber requirement. I would never suggest, of course, that this be used in place of marine rope. As already mentioned, this morning, I had a sample sand bag made for the Corps of Engineers, but somebody seems to have become very much attached to it. However, here are some yarns made from decorticated kenaf that we spun last week. We are now making some samples for the Quartermaster Corps and the Corps of Engineers. This is the finest yarn that we have been able to spin out of kenaf, mechanically decorticated kenaf, that is. This is about an 8½ pound yarn. At first we did not think it was possible to spin the fiber into as fine a yarn as this; but here it is, a fact and no longer just a hope.

I want to emphasize again that what we want above everything else is some fiber production out of Florida. We would like to get a substantial amount of fiber from you people down here. I am quite sure that the soft fiber manufacturers in this country will support your program if you get your costs down to where we can afford to buy it. We are exceedingly anxious to see you people make a success of it; to see a real volume of business built up in this particular field. I guess that is about all I have to say. I will be around for a time if any of you wish to ask any questions.

CHAIRMAN:

Are there any questions anyone would like to ask? . . . It looks as if you have already answered them, Mr. Guthrie. We certainly do appreciate the enthusiastic and helpful part you have taken in both sessions of our program on fiber crops today. It is our hope that ultimately we may be able to give you all the kenaf of the very highest quality that you can possibly use in that wonderful plant you have up there in Allentown of which I have heard so much.

I would now like to call on Mr. Edward G. Henriquez, President, Tropical Fiber, Inc., Vero Beach, for any comments he may care to make on the discussions that have gone before or regarding his extensive experience with kenaf both in Cuba and in Florida.

MR. HENRIQUEZ:

Members of the Soil Science Society and Friends: As one of the first planters of kenaf for commercial purposes, both in Cuba and in the United States, I have been at it for a number of years and, in more or less the hard way, have found out about many of the still unsolved difficulties in the harvesting and processing of this crop.

The agricultural phase of the project has been fairly well attended to. The work under way in Cuba has been quite inclusive and has continued to lead the way insofar as improvement of the plant by breeding and selection is concerned. They are doing more on that phase over there than we are over here because they have had a longer start. They also have had some very good men working on it. On the other hand we are just starting work on this crop over here. I am sure that we will be doing as well, given the same amount of time.

It has been pointed out by several speakers that once you get the crop grown you have to harvest it. We tried to harvest our first commercial crop in Florida in 1949 with the old war-time hemp harvester. This does a fairly satisfactory job insofar as ramie and the shorter kenaf growths are concerned, that is, if you take your time and have plenty of help. The machine is quite complicated, however, and requires an experienced operator as well as quite a bit of mechanical help on the side to keep it going. It does the job, however, and, as the only thing available, it has filled the bill up to now, though it has done especially poorly on the taller kenaf.

However, we are going into commercial production on a very large scale and that has called for a new approach which we and other companies have tried to find. As you have seen from the graphs that have been discussed by Mr. Randolph you have almost as many small, no-account stalks that have very little fiber in them as you do good stalks. This fact impressed us at the very beginning, together with the thought that with the natural orientation of the stems in the field, the method of approach in harvesting should be to try to keep them standing upright in a fully parallel position just as long as possible. This would also include the avoidance of rapid changes in movement, which, when actuated at one point, often cause broken stems.

We have attempted certain basic improvements in our harvester which in brief consists, in part, of a vertical gathering attachment mounted on top of a tractor-trailer mowing machine. The gathering chain is operated near to the horizontal and it is so placed as to grasp and collect only the tall, more mature, fiber-bearing stalks, which are deposited in a windrow at the present time. However, we plan to add a bundling attachment to our harvester in the near future. The gathering chains operating above the tops of the short, immature plants means that they and anything under that height are thereby discarded in the harvesting operation.

We also have attached to the front end of this tractor an elevated cutter bar which can be managed by the operator of the tractor in a way to eliminate the leafy top of the plant. This is done by catching the tops, as they are cut, in a narrow, trough-like conveyor located at the rear of this high cutter-bar which moves them to the side of the swath and drops them on the ground. Thus we have made a composite machine which tops the plants so that the stalks are all of an even height (which is the beginning of your grading system) and then gathers those stalks and cuts them off as near to the ground as the adjustment of the cutter-bar will allow. Thus we avoid the usual high stubbles left by the old binder. In other words we recover more of the lower part of the stalk in which the greatest concentration of fiber is found. By eliminating the shorter plants (about 3 feet and under) in a manner already indicated we are also eliminating the weeds, grass, etc., that otherwise would be included for processing at the next succeeding operation.

Although this fiber question has been covered very thoroughly in this meeting, I am going to digress a bit from the problems of actual harvesting to discuss a little further the importance of high quality, straight fiber which the mills have a right to expect and require. Not only that, they require clean fiber. The cleaner it is the better the price. As was pointed out just a little while ago, ramie grown in China (China grass of commerce) in the past has always been very heterogeneous or ununiform in contrast to the comparative uniformity of the Florida product.[3] The same thing might be said of kenaf grown in India where the harvesting and handling is by hand and the retting and cleaning is usually in foul, silt-laden water by the same primitive means; likewise in the instance of abaca grown in the Philippines in which I know that sometimes the losses run as high as 50 percent on a weight basis because of dirt and trash of many kinds that have been found in the bales that come from off-shore. Fiber conditions can explain why Florida ramie at 28-30 cents per pound might be preferred to the China Grass of Commerce even though the latter has sold as low as 3 to 8 cents per pound! All of this I mention largely to bring us back to the point Mr. Guthrie brought up a while ago, that we have got to prepare for 12 cent fiber in the instance of kenaf if the industry is to survive though quality production on our part may quite appreciably broaden this price base since, after all, it is clean, straight quality fiber that the manufacturer wants and its losses in the manufacturing process are comparatively small.

In the harvesting procedure[4] we are developing, as has already been explained, we are eliminating and leaving trash in the field which at the present time is only adding weight to our handling and hauling costs and cluttering up the machines which do the harvesting and ribboning or decorticating. That is to say, all that trash that the old harvester-binders pick up and put into the bundles along with the good plants creates volume and weight which has to be handled and rehandled and this costs money. In the end it also reduces the quality and value of the fiber produced because the small, short fibers that do get through tend to degrade the fiber that you are selling. Therefore, in my opinion, we have to start right at the very beginning in harvesting and eliminate as much of the undesirable material as possible.

I sincerely hope that tomorrow, in the course of the field trip that has been planned to the Glades, we will be able to show you this first attempt at approaching the harvesting operation from a new point of view for these tall, fiber plants The appearance of the field behind this machine is not as neat and tidy as it is following the passage of the old type of machine because it doesn't pick up all the trash. It leaves it on the ground where it belongs. Many small stalks lying there make you think that it is inefficient and doing a poor job. Perhaps it is actually being a little bit too efficient. However, it is greatly reducing the mass of plant material that must be handled and from which you are really going to get the better quality of commercial fiber. Thank you.

CHAIRMAN:

Thank you, Mr. Henriquez. We are happy to have Mr. Joe Walker with us this afternoon. Mr. Walker is presently Director of the U.S.D.A.'s cooperative fiber production study in Cuba. He will now tell us something of the work with kenaf that is under way down there in cooperation with the Cuban Government.

MR. WALKER:

Mr. Chairman. Members of the Soil Science Society, Ladies and Gentlemen: In my opinion one of the most interesting things about this kenaf program hasn't been mentioned today. I refer to the history behind it. While such a discussion may not have any particular economic value perhaps you might be interested in hearing something of it.

Kenaf was first introduced into Cuba in 1918 and the seeds were lost in a year or so. It was reintroduced in 1933 and the project went so far at that time as to

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[3] This was very strongly emphasized by Mr. Harry Neiman, Sea Island Mills, Inc., in his talk on the subject of degumming before the Society at the time of its meeting in Belle Glade in April 1947 as reported in Proceedings Volume VIII, pp. 141-143, 1946-7.

[4] Note: A couple of views of the new type of harvester which Mr. Henriquez has discussed and a view of the ribboner he is developing are to be found as Figs. 2 and 3, page 243 of the Appendix.—Ed.

develop plans for the construction of a sack mill when the seed sources were lost again. However, in 1942, Mr. Acuna and an associate of his in the Cuban Government brought in fresh supplies from San Salvador and from that time on we haven't lost the kenaf seed supply. At that time Mr. Acuna brought back three pounds and on account of this introduction and the care given the seed he might be regarded as the father of the modern kenaf program down there.

A few months after that, in 1943, an army bomber flew over from San Salvador and left seeds in most of the West Indian Islands. Some four or five hundred acres were grown in Cuba that year. Enough seeds were produced the following year, Mr. Guthrie, to decorticate over 20,000 pounds of fiber. And it was fiber from that crop that was used to make the first sugar sacks that we made from Cuban kenaf. However, when the time came to make those sacks we couldn't find a mill in the United States that could weave them until we happened to learn that there was a small pilot-sized jute mill in San Quentin Prison. A fair sized sample of the fiber was first sent to Pennsylvania for spinning and thence to the San Quentin Prison for weaving. About five sacks were woven from it.

Since that time most of you are familiar with the modern kenaf program. When that plane landed those seeds in Cuba none of us had heard anything about kenaf and Mr. Horne, who was then working in the Experiment Station in Puerto Rico, received orders to go receive a load of kenaf seeds which the Board of Economic Warfare was sending. He and Mr. Acuna, working with officials in the American Embassy in Havana, then developed a cooperative program to answer the current need. It was from this that the present program grew.

I first went to Cuba in 1945. My predecessor there, Dr. Julian Crane, did the preliminary agronomic experiments and my work more or less expanded and substantiated what he had already found. I think one of the most important contributions we have made down there that has not been given much attention, as yet, because of the overshadowing problems in the mechanical extraction of the fiber, is the breeding work that has been done.

Those seeds that were introduced from Salvador were a mixture of four varieties. They came in a very round-about way to Salvador, we think from Java. They reached Java in the hands of a Dutch diplomat who gave them to one of the representatives in the diplomatic service of San Salvador who took them back to the President. A small supply of these seeds was given to an American who thought that they might have a future down there and so he multiplied them to the more than 2,000 pound supply that was sent to the West Indies by 1942. Previous to that time some kenaf seed had been sent to Peru and the best information we can get is that those also came from Java though they do not bear very much resemblance to the ones we got from Salvador. In 1945, however, we also introduced those into Cuba and I made some crosses of the two varieties introduced in 1947. As a result we now think the prodigy of some of those crosses will open up about 20 degrees of the Earth's surface as a belt around the equator for kenaf production where, before, it was thought that this crop could not be grown. These new strains are not so sensitive to day length as the earlier ones we were working with and it appears that they will produce fiber down closer to the equator where there is a heavy rainfall and exceedingly fertile land and the plant makes very rapid growth. We had nine-foot kenaf in sixty days in Salvador this year. I planted kenaf seeds there one Wednesday afternoon and by Sunday morning the young plants were three inches tall.

With reference to the extraction work that all of us are doing, I can't add much to what has already been said. We all seem to be pursuing essentially the same course and using more or less the same methods with some small variations. I believe the best thing we can do, and I think my Cuban associates will endorse this, is to invite you to come down there and study our work just as you have so cordially allowed us to study your work up here. I am sure you will always find our latch string out just as we are finding yours up here.

In certain cultural operations we are doing a little differently down there but I don't think the difference is sufficiently great to try to point them out here, especially since our conditions are so different. Thus we don't exactly agree on the methods of harvesting seeds. We are not going to combine ours directly, certainly not the Kenaf Corporation. However, some of the other growers are going to try it. We fear that there is going to be too much moisture in the seeds if they are threshed directly in this way and we would run into trouble from moulding, and consequent loss of viability. The Kenaf Corporation is going to cut the seed crop with binders, let the bundles dry in shocks and then thresh them. Last year we found that we

could run our yields up quite appreciably by harvesting in this way. We have combined successfully in Cuba but the yield has always been low. I don't recall any yield from combining ever running over 250 pounds per acre. Last year we had yields running over 600 pounds by using binders and then threshing. That was on areas of up to 33 acres. We actually averaged over 400 pounds on more than 200 acres by harvesting in this manner.[5]

Of course you should cut the kenaf when you think you will get the most seed. In Cuba, then, we recommend harvesting for threshing when there are three to five dry capsules. The greener the stems are the smaller the bundles and shocks will have to be so as to get good ventilation. If your kenaf is perfectly dry there is no reason why you should not combine it. Unfortunately, we don't get it dry enough down there until it is so late that most of the seeds are lost.

Thank you for your attention. I'd be glad to try to answer any questions that any of you may have.

QUESTION:

What kind of binders do you use?

ANSWER:

We are using the so-called war-hemp binder which was originally a John Deere harvester-windrower for hemp to which has been attached an International binding head.

QUESTION:

What kind of thresher are you using?

ANSWER:

We are using International threshers and International combines, as well as John Deere and Massey Harris.

QUESTION:

Do you have to change the threshers?

ANSWER:

No. They are all made for rice and we have made no modifications on them except to adjust the screens. They all have adjustable screens.

QUESTION:

Do you have to tie the shocks?

ANSWER:

No. We don't tie them. Many of them fall down but we go back and set them up again. We shock them with open centers, so the air can get through them. Kenaf will carry 85 percent moisture in wet weather when it is green.

CHAIRMAN:

Are there any more questions? . . . If not, we would now like to hear from Mr. DeWitt Knox, Vice President of American Kenaf Corporation, who has been exceedingly busy during the past few months setting up the Corporation's large Mohegan Corona decorticator and getting it into operation on kenaf out in the Glades.

MR. KNOX:

Mr. Chairman, Ladies and Gentlemen: Since the discussion would seem to be about at an end I don't know whether I am to be considered lucky or unlucky. Perhaps I am sort of a fifty-fifty individual because the good services of the Experiment Station and of the Department of Agriculture have given me lots of help as well as lots of headaches. I think if Mr. Whittemore had spoken to me this morning about the disadvantages of the field ribboner I might have helped him out quite a little bit. We have decided to try this field machine by building three of them and I never know when I get up in the morning whether I am going to have a headache or a picnic. Up to now I've had lots of headaches.

Our field program out there is essentially as outlined by Mr. Guthrie in connection with the work he is doing in Cuba. We have taken this U.S.D.A. machine

[5] The binder and combine to which Mr. Walker refers are shown in the photo series covering the Field Trip, beginning on page 175.—Ed.

and, with the help of workers at the Experiment Station, undertaken to adapt it to producing ribbons from kenaf and carrying them to the central decorticator which, in our case, happens to be a Mohegan Corona type as referred to by the Chairman. We run these ribbons through the decorticator and get a limited amount of nice clean fiber which is ready for drying and baling.

There has been a terrific amount of work done by the Agricultural Department of the Corporation in getting about 700 acres of land ready and planted. They have done a marvelous job and have really been pushing me with those plants. As has been said, if you were to go south on Highway 7 you would see some fields of kenaf in blossom that are intended for seed production. However, if you come out to our plantation tomorrow you will find that we are growing our crop for fiber and not for seed. Consequently we are harvesting and producing fiber at this time.

I don't exactly know what the chairman had in mind when he suggested that I take part in this discussion. Unfortunately, I was so busy in the field that I could not attend the meetings yesterday and this morning. However, from what I have heard this afternoon I feel that about all the salient points have been very well covered. However, there is nothing like a physical view of what you have heard discussed so I hope you will be able to come out to see us tomorrow. Do you think of anything else, Mr. Chairman, that I might add to this discussion?

CHAIRMAN:

Not unless you might be willing to idealize a little bit and tell us just what you would like to have in the way of equipment to more efficiently handle the crop you are working with.

MR. KNOX:

Mr. Byrom expressed my thoughts perfectly when he said we need a machine that will handle production with low waste. My principals come out there and look at what I am doing and say the waste is terrible, can't we do something about it! Of course, all that waste means dollars, plenty of them, and the quicker somebody develops a machine that will turn a larger percentum of the fiber contained in those plants into money, why the sooner we will all be a lot happier.[6]

CHAIRMAN:

Are there any questions you want to ask Mr. Knox before he scoots back to the field? . . . If there are none I should like to again remind those of you who plan to go on the field trip tomorrow to let us have your name on the list just as soon as possible. The principal stopping points will be at Newport Industries, Inc., where the ramie harvest is actually under way, then the Everglades Experiment Station, followed by the plantation of the American Kenaf Corporation, where the first harvest of kenaf on a large scale in Florida thru the use of mechanical decortication is under way. The bus will leave the hotel at 9:00 A.M. There is no meeting this evening.

Before closing the afternoon meeting, however, I should like to call on Mr. Georges Brouillette of Clermont, Florida, who has been working with Dr. Charles R. Short during the past couple of years at the Florida Industrial Laboratories in that city on certain ribboning and degumming devices for the harvesting and processing of bast fibers. Unfortunately, Dr. Short could not be with us today on account of illness.

MR. BROUILLETTE:

Mr. Chairman, Ladies and Gentlemen: I am indeed glad to say a few words regarding our work up at Clermont for Dr. Charles R. Short, who, being ill at this time, could not attend this meeting, as your Chairman has said. I can assure you that he would have liked very much to be here with you.

As many of you know, Dr. Short became interested in the possibilities of a soft fiber industry in Florida some eight years ago and has made extensive studies since that time of the many problems that are involved. After much thought and consultation with many fiber specialists, it became apparent that the pricinpal "bottleneck" was in the mechanization of the harvesting and the ribboning or decortication of

[6] Some of the operations on Am. Kenaf's Plantation will be found in the photo series covering the Field Trip beginning on page 175. -Ed.

such plants; and that if these types of fibers were to be produced economically in Florida new machines for this purpose would have to be developed.[7]

With this in mind he diligently set himself to the task of designing and building a small type of ribboner that the individual farmer could buy and operate economically. Tremendous strides have been made in these developments. Dr. Short's health permitting we will make field tests of the ribboning machine in the near future.

It has been my pleasure for the past year and a half to work for and with Dr. Short in the building and testing of this machine. As a matter of fact we have been working on two machines, the one referred to above we call a field ribboner or decorticator: the other is a chemical degummer and washer for cleaning up the ribbons of either ramie or kenaf by way of preparing them for further processing and spinning.

All of this work has been helped to a great extent by the ever-cooperative efforts of Dr. Allison and the staff at the Everglades Experiment Station. I thank you for this privilege of speaking to you.

CHAIRMAN:

Thank you, Mr. Brouillette. I am sure we all hope for Dr. Short's complete and speedy recovery. Will you kindly convey our every good wish to him at the first opportunity! If there are no other questions . . . the meeting is adjourned.

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[7] A general view of the field ribboner developed by Dr. Short will be found on page 243 in the Appendix, Figure 1.

EVERGLADES FIELD INSPECTION TRIP FOR RAMIE, KENAF AND SANSEVIERIA

October 31, 1951

A group of more than 50 delegates left the George Washington Hotel by chartered bus, and many others in private cars at 9 o'clock on the morning of the 31st, following the close of the Annual Meetings of the Society on the afternoon of October 30.

The FIRST STOP was at the plantation and mill of Newport Industries, Inc., east of Canal Point. The general operation of this unit in the field and in the mill was fully explained by Mr. J. M. Dempsey and his associates to whom the entire group was deeply indebted for such a complete view of the operation which has become of world-wide interest. The series of photos that follow show some of the operations involved in this project, though all of the pictures were not necessarily taken on the day of the tour.

NEWPORT INDUSTRIES (Ramie)

Figure 1. An early air view of the central plant at Newport Industries, Inc., Canal Point, showing extensive areas of ramie in the background and yard-drying of the fiber, a practice that has been discontinued in favor of oven drying as illustrated in Figure 12 of this series.

Figure 2. Digging ramie roots with a potato digger for planting new areas. While this operation was not observed during the inspection of the plantation operations, this is the way it is being done.

Figure 3. Gathering the roots that have been surfaced by the operation in Figure 2 preparatory to chopping and planting.

Figure 4. Planting ramie roots, 4 rows at a time, from rhizomes and crowns that have been harvested and gathered as shown in Figures 2 and 3. The rows are spaced three feet apart with planting pieces dropped at intervals of about two feet in the row.

Figure 5. Air view of harvest operations on the plantation of Newport Industries, Inc., showing three binders and two loaders in action with numerous field wagons awaiting loading. The seemingly limitless expanse of the Everglades is well shown in the background.

Figure 6. Close up of harvesting operation with war-time hemp harvester. Note self-tripping bundle carrier at right which was designed by and built for Newport Industries, Inc. This will carry a load of 800 - 1000 pounds and saves the hand labor involved in piling bundles manually.

Figure 7. Close up of grapple hook and Speed Loader mounted on D-4 tractor as adapted to loading sugar cane and, in this instance, ramie. Note the piling of bundles in the background preparatory for the use of the loader. This was before the bundle carrier had been installed on the harvester.

Figure 8. A close-up of loading operations using a Speed Loader to rapidly fill the train of Athey wagons.

Figure 9. Arranging ramie bundles on feed table at central plant as the apron approaches modified Corona decorticator at the left.

Figure 10. Ramie mat approaching decorticator at end of feed table on the left and decorticated fiber leaving the machine on the right. Note the two encased raspador units, one in front of and the other at left of man at top of picture and waste leaving upon separate carriers from each thru the back of the building.

Figure 11. Decorticated ramie fiber after passing through the squeeze rolls which remove a considerable amount of the free water it contains as it leaves the Corona where it has been thoroughly washed during the decorticating process.

Figure 12. From the squeeze rolls the wet fiber is taken to the drying ovens via the "dolly", as shown in this photo. Thus only a few minutes after decortication has taken place the fiber is dried and ready to bail.

Figure 13 Bailing dried undegummed ramie fiber after it comes from the oven in preparation for storage or shipment

Figure 14 Weighing and warehousing bailed ramie at Newport Industries Inc Canal Point Here the product is at an intermediate point between field production and industrial use

Figure 15 Manufacturing ramie leaf meal from the tops of the harvested plants This is a high protein (22 24 %) feed for livestock and poultry Although its manufacture has been temporarily shelved in favor of chemical defoliation in the field there is always the possibility that it will be resumed in due course

Figure 16 Undegummed ramie in wrapped bales in process of loading for shipment from Canal Point The wrapped bales are for export Mr J M Dempsey manager of the Fiber Division of Newport Industries Inc at Canal Point is shown holding a small armful of the undegummed fiber

EVERGLADES EXPERIMENT STATION

The SECOND STOP following luncheon in Belle Glade and elsewhere along the route was at the Everglades Experiment Station, about 2½ miles east of Belle Glade on the Palm Beach Ft Myers highway Here a considerable amount of investigational work and research is under way on the agronomic and engineering problems associated with fiber crop production in South Florida— particularly ramie, kenaf and sansevieria—as discussed during the two days of meetings that immediately preceded the field trip As in the instance of the field inspection of ramie at Newport Industries Inc only a few of the high points of this stop will be shown in the figures that follow These will include reference to various problems observed and discussed along the way though not necessarily seen or discussed at the time of the Experiment Station visit

Figure 17 An view of the Everglades Experiment Station from the north (left) and (right) from the south showing more details of plot layout to the right of the roadway running across the lower left hand corner of the picture

RAMIE

Figure 18 Ramie variety plots at the Everglades Experiment Station

Figure 19 A good stand of mature ramie ready for harvest

Figure 20 Ramie inflorescence with female type blossom above and the male pollen bearing type below

Figure 21 Partially decorticated stems showing the peripheral location of the bast fibers and their abundance in this type of plant

Figure 22 Ramie flow chart showing various steps in processing and use of the fiber from the crude decorticated ribbons ("China grass" of commerce) to the finished yarns

KENAF

Figure 23 Kenaf blossom Note the hibiscus type

Figure 24 Section of mature kenaf stems at left with seed pods center and seeds exposed on right

Figure 25 Kenaf variety plots at Experiment Station with Mr Charles C Seale fiber crop agronomist as the measuring stick

Figure 26 A mature growth of kenaf at about 110 days of age on a typical mineral soil Pompano fine sand in the Indiantown area

Figure 27 Harvesting mature kenaf for seed with a war time hemp binder This is an operation of Tropical Fibre Inc Vero Beach Florida

Figure 28 Field view of kenaf shocks ready for threshing with the combine shown at the right This is an operation of Tropical Fibre Inc Vero Beach

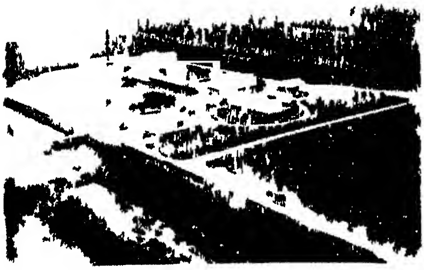
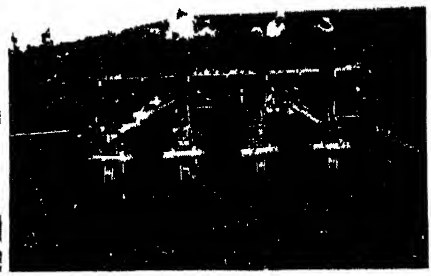


Figure 1

Figure 2

Figure 3



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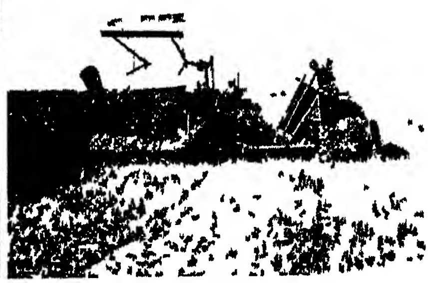

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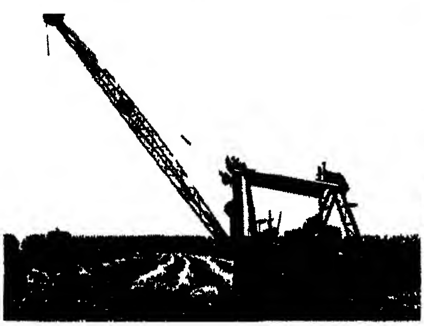


Figure 7

Figure 8


Figure 9


Figure 10


Figure 11

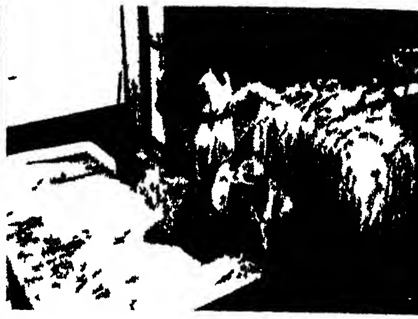


Figure 12

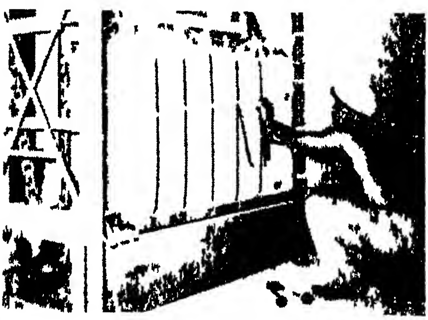
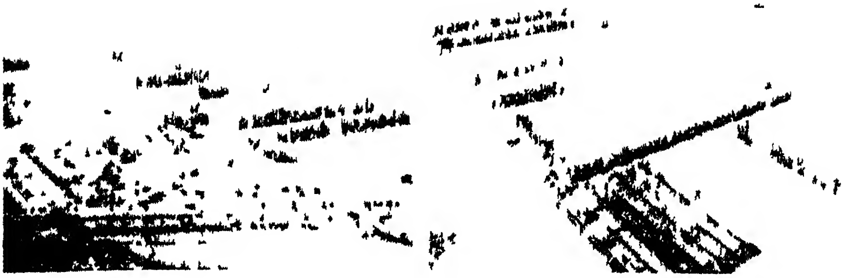


Figure 13


Figure 14


Figure 15


Figure 16



(Left) Figure 17 (Right)

Figure 18

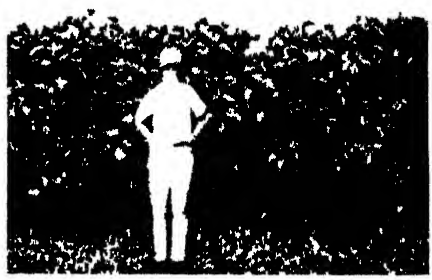


Figure 19

Figure 20

Figure 21

Figure 22

Figure 23

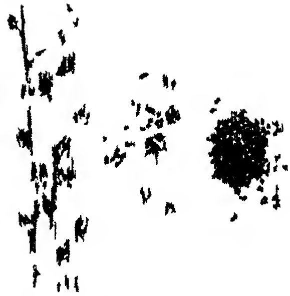


Figure 24

Figure 25

Figure 26

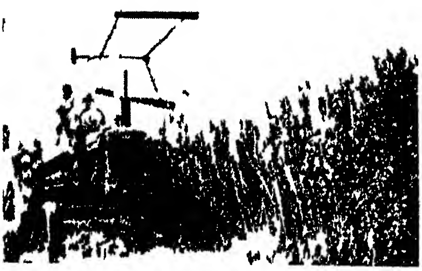


Figure 27

Figure 28

Figure 29

Figure 30

Figure 29. Top blight of kenaf which was thought by some at the time of the meetings to be a form of virus disease but later found to be definitely associated with infection by *Colletotrichum* sp.

Figure 30. An area of plants in a kenaf field badly affected by the root knot nematode with the almost complete destruction of the root system is shown by the inset photo of plant roots from another area.

Figure 31. Harvesting problems can be caused by the wind when the kenaf crop is mature and heavy in the top growth. The wind was not blowing at the time the picture was taken as might be judged by photographer Averill's mussed hair and the bowed plants.

Figure 32. Harvesting problems also can be the result of planting kenaf seeds contaminated with morning glory. Above, ground view of the impossible condition that developed in the course of only a few weeks of growth with an air view of the same field (below) showing an exploratory path that had been cut across it with the harvester before the flight photo was made in an effort to determine the extent of the infestation. Such a condition forced abandonment of this entire 60 acre field as well as several others.

Figure 33. This is a part of the kenaf waste referred to in the discussion of the decortication problem by Mr DeWitt Knox towards the close of the program in West Palm Beach just prior to the field trip.

Figure 34. A large part of the harvesting difficulties associated with the handling of bast fibered crops such as ramie and kenaf has been associated with the derelict equipment it has been found necessary to use up to the present time. Thus the war time hemp binder, a poor job though it has done, is no longer made and many of the critical parts necessary for replacement no longer can be obtained except by special order. All credit to it however for the start it has given the bast fiber industry in Florida.

SANSEVIERIA

Figure 35. A cultivated stand of *Sansevieria thyrsiflora* Thunb. (*S. guineensis* Willd.) growing in mineral soil at Boyton, Florida.

Figure 36. Decorticating demonstration at the time of the field trip with the large Corona type machine built to the design and specifications of U S D A engineers by a Baltimore firm. The first drum is readily visible between the two men at the feed table, Mr Byrom right and Mr Whittemore left.

Figure 37. Standard bale of sansevieria fiber weighing about 100 pounds as prepared at the Everglades Station for U S Navy tests. This was taken from plants gathered from widely distributed areas over South Florida.

AMERICAN KENAF AND FIBER CORPORATION (Kenaf)

The THIRD AND LAST STOP on the field trip was at the Plantation of the American Kenaf and Fiber Corporation on the lower Hillsboro Canal southeast of the Experiment Station and really out in the heart of the Everglades. In view of the fact that this entire operation was broken out of virgin sawgrass soil (Everglades peat) beginning only a little more than a year before the time of the visit, August 1950 to October 1951, photos of several of the land preparation operations will be included in the figures that are to cover this stop. The whole party is indebted to the officials of the above corporation for their hospitality and the completeness of the study which they were permitted to make of the entire operation.

Figure 38. Native sawgrass of the Florida Everglades. It is from the roots of this heavy sedge that Everglades peat largely has been formed.

Figure 39. "Chopping", is one of the first land preparation operations in the Everglades where there is not too much heavy shrubby growth such as willow. It simply consists of running the heavy vegetation down so the plow can turn it in.

Figure 40. Plowing the brown fibrous peat with a two disc unit.

Figure 31

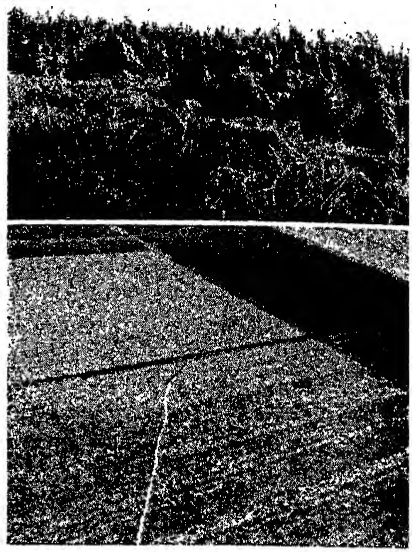


Figure 32

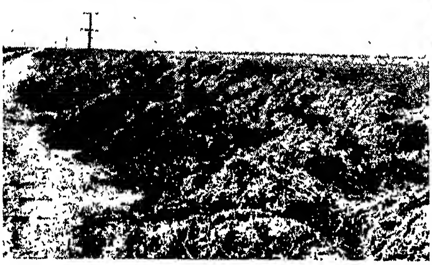


Figure 33

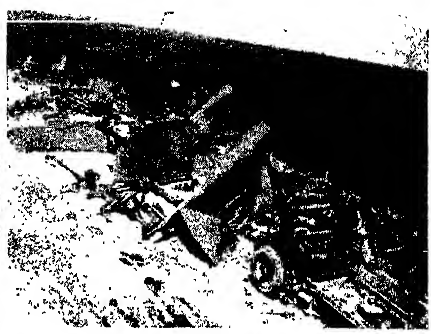


Figure 34

Figure 35

Figure 36

Figure 37

Figure 38

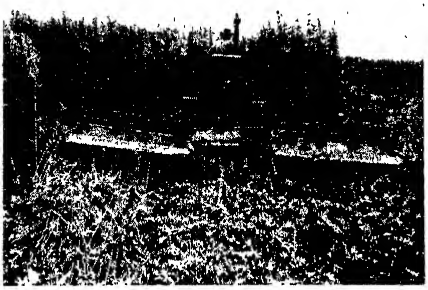


Figure 39

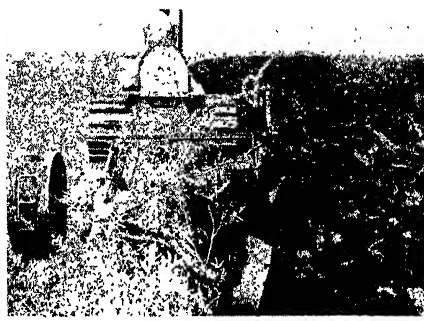


Figure 40

Figure 41

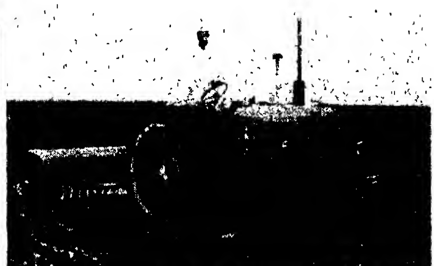


Figure 42

Figure 43

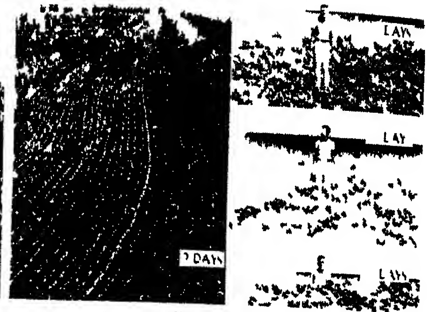


Figure 44

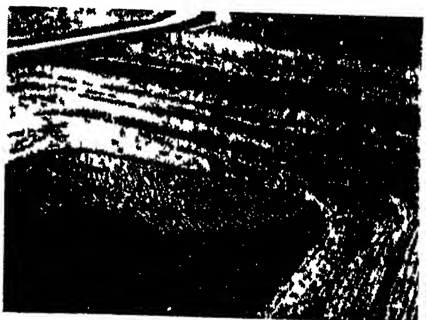


Figure 45

Figure 46

Figure 47

Figure 48

Figure 49

Figure 50

Figure 41 Harrowing and leveling the peat soil after plowing The fibrous character of this soil is well shown in this operation

Figure 42 Distributing fertilizer broadcast by drilling just prior to seeding

Figure 43 Drilling kenaf seed with a standard rice drill For fiber production the rows are spaced about 7 inches and rate of seeding about 20 pounds per acre depending somewhat on viability of seed

Figure 44 The growth rate of kenaf in the moist warm Everglades peat is well shown by the photos taken at 2 7 15 and 55 days following seeding

Figure 45 The kenaf harvest is viewed from the air Center (...) showing binder in operation with a twin drum ribboner working at the outer edge of the bundle strewn area Note difference in appearance of bundle covered area and the trash left after the passing of the ribboner

Figure 46 Ground view of one of the modified hemp binders at work harvesting kenaf Note loose poorly tied bundles

Figure 47 Ground view of twin drum ribboner at work This ribboner was developed by U S D A workers at the Everglades Station Note scattered boxes of ribbons awaiting transport to the central plant for decortication

Figure 48 Ribbons from field boxes being placed on the decorticating line at the central plant

Figure 49 Field ribbons entering the first wheel of the decorticator This procedure was never developed to a point where the losses of fiber were not excessive

Figure 50 Kenaf fiber leaving the squeeze rolls and ready for the drying oven

Figure 51 Kenaf entering (above) and leaving (below) the experimental drying oven at the Everglades Station where most of the 1951 crop was dried

Figure 52 Kenaf fiber in the bale warehoused and ready for grading

Figure 53 Yarns and burlap bagging in various forms manufactured from mechanically decorticated kenaf

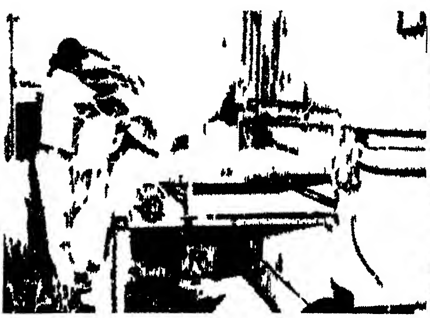


Figure 51

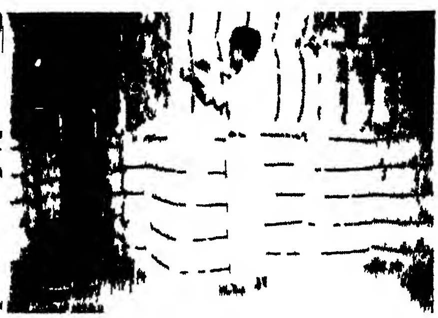


Figure 52

Figure 53

BUSINESS MEETING

A brief business meeting was called by Vice President Wander immediately following the close of the Panel Discussion on Soil and Water Conservation on the evening of October 29. Dr. Wander presided in the absence of President Carrigan.

A telegram was read from Dr. Carrigan expressing his deep personal regret over his inability to be present at the meetings due to the heavy responsibilities of his new position at the Armour Research Foundation in Chicago.

Chairman Wander announced that essentially the only business to be taken care of during the meeting was the election of a Vice-President, the present Vice-President, according to the dictates of the constitution of the Society, automatically becoming President by that action.

The Nominating Committee that had been appointed during the morning meeting, which was made up of Dr. W. T. Forsee, Jr., Mr. E. B. O'Kelly and Mr. V. E. Woods, with the last named acting as Chairman, was asked to report.

In presenting the report Mr. Woods advised that the committee had met during the late afternoon. It seems that after having heard a certain paper during the morning meeting on "Sodium and Potassium Interrelationships in Pangola Grass" they came rather quickly to the unanimous decision that Dr. Nathan Gammon, Jr., should be nominated to this important responsibility. After formally nominating Dr. Gammon to the elective office of Vice-President of the Soil Science Society of Florida as the choice of his committee, Mr. Woods then took the opportunity, in behalf of the committee, to move that the nominations be closed and that the Chair instruct the Secretary to cast a unanimous ballot to certify his election. Following the usual call of the Chairman for nominations from the floor, and receiving none, a second to Mr. Wood's motion was requested and received simultaneously from a half dozen or more members. No negative vote being received, following the question, the Chairman followed the usual convention and instructed the Secretary to cast a unanimous vote by which Dr. Gammon became the new Vice President for 1952.

The Secretary was then asked to read the Resolution of Sympathy that had been prepared for members who had departed this life during the year and requested a short pause after the reading. The resolution will be found on page 187 of this Proceedings.

There being no other business to come before the meeting the President asked for a very brief meeting of the Executive Committee immediately following adjournment. The meeting was declared adjourned at 10:45 P.M.

MEETING OF EXECUTIVE COMMITTEE

At a short session of the Executive Committee President Wander, as Chairman of that Committee, extended a cordial invitation for the Society to hold its 1952 meetings at the Citrus Experiment Station, Lake Alfred. This was tentatively accepted and program plans discussed in a preliminary way. In filling the position of Secretary-Treasurer, R. V. Allison of Belle Glade was again appointed to that post. There being no other business to come before the committee the meeting was adjourned at 11:15 P.M.

RESOLUTION OF SYMPATHY

Soil Science Society of Florida

WHEREAS, death has taken from our rolls during the year 1951 the following esteemed members of the Society whose sincere and constructive interest in all aspects of the work will make their absence keenly felt for a long time to come.

NOW THEREFORE. BE IT RESOLVED, that this expression of sorrow over this great loss and of sympathy to the immediate families of the deceased be spread upon the records of this Society and a copy of same be sent to the closest member of the family of each.

MR. EDWIN L. ANDERSON Lima, Peru	MR. G. A. NICOL, JR. Palm Beach, Florida
DR. B. R. FUDGE Jacksonville, Florida	MR. HARRISON RAOUL Belle Glade, Florida
MR. E. T. HALTER Palm Beach, Florida	MR. J. GLENN RAWLS Plymouth, Florida
MR. B. G. KLUGH Birmingham, Alabama	MR. J. D. WARNER Quincy, Florida
MR. R. K. LEWIS West Palm Beach, Florida	MR. J. S. WILLSON Palm Beach, Florida

By the Resolutions Committee,

LUTHER JONES, *Chairman*

A Resolution Addressed Particularly to the Various Boards of County Commissioners of the Central and Southern Florida Flood Control District, Pertaining to the Urgent Need for Their Fullest Possible Cooperation in the Planning and Construction of Roads and Highways as an Operation of the Very First Importance in the Organization of Any System of Water Conservation and Control for a Given Area That Is Economical in Its Construction and Maintenance and Efficient in Its Operation.

WHEREAS, the adequate conservation and handling of Florida's water resources has rapidly mounted to a place of very first importance during the past few years because of rapid increase in population and extension of agricultural development; and

WHEREAS, the development of a system of roads is as necessary in promoting the use of the lands as the construction of the system of water control: and

WHEREAS, the construction of ditches and grades and other physical installations and adjustments normally associated with proper road and highway planning and development can become an item of first importance, either for better or for worse, in the planning of a proper water control installation for a given area and its subsequent maintenance; and

WHEREAS, The Board of County Commissioners, as duly elected public servants, exercise a very great amount of authority in determining the location, design, construction and maintenance of highway and road systems in their individual counties and consequently in the State as a whole both on their own responsibility and in cooperation with the State Road Board.

NOW, THEREFORE, BE IT RESOLVED, that this meeting go on record as importuning, through this resolution, all Boards of County Commissioners in such counties or parts thereof as fall within such water control units as Central and Southern Florida Flood Control District to take the fullest possible cognizance of these needs for coordinated effort in all matters pertaining to Water Control and Conservation and to give the fullest possible cooperation in the physical development of same insofar as cooperation in the location and design of roads and highways and physical installations pertaining thereto are found, or could be found, to play an important and helpful role in this vital phase of our conservation planning for the future that is so vitally needed.

BE IT FURTHER RESOLVED that a copy of this resolution be sent, at the time of publication, to the Office of the Governor; to the Commissioner of Agriculture, Tallahassee; to the District Office of the Corps of Engineers, U. S. Army, Jacksonville; to the Chairman of the State Road Department: to each Board of County Commissioners throughout the State; to the State Chamber of Commerce; and to any and all State, County and Local Officials who may have or should have interest in the subject matter of same, including the Water Conservation Committee of the Resources Development Board of Palm Beach County in West Palm Beach.

R. V. PATTERSON, Clewiston
HARRISON RAOUL, Shawano
JOHN C. STEPHENS, Ft. Lauderdale
LUTHER JONES, *Chairman*, Belle Glade

RICHARD A. CARRIGAN
1951 — Retired

OFFICERS OF THE SOCIETY
1951

RICHARD A. CARRIGAN	President
I. W. WANDER	Vice President
W. T. FORSEE, JR.	Member Executive Committee
R. V. ALLISON	Secretary-Treasurer

APPENDIX

The subsidence of Everglades peat under drainage and cultivation as viewed early in the development of the Everglades Experiment Station. Quotation from Florida Experiment Station Bulletin No. 190, The Stimulation of Plant Response on the Raw, Peat Soils of the Florida Everglades Through the Use of Copper Sulfate and Other Chemicals, p. 80, 1927.

"One of the most important problems from the agricultural standpoint of peat soil in general is that of shrinkage and excessive drying as a result of drainage. If the Everglades is to develop into a durable agricultural project more importance should be placed upon this than any other single consideration.

"In order adequately to protect peat soils against fire and conditions of excessive drought. absolute water control will be necessary and this should be the aim in starting an agricultural development of this nature. In the case of excessive drought, even in the absence of fire, such conditions tend to accelerate natural oxidation processes and result in a further net loss of the material.

"From this standpoint in particular the whole project is not a problem for the engineer alone. It is rather one in which agricultural research must play an important part in developing systems of cropping and rotation that will coordinate with the condition and movement of the water table in such a way as to afford maximum protection against this loss. To those who have a broad, sincere interest in the development of this area as a state resource, the matter of subsidence and water control cannot be over-emphasized. Indeed, we have need but to refer to the experience of the English upon the Fenland of that country where, with time, strata of peat several feet thick have almost disappeared and drainage lines and cultivation are now largely in the clays with which the peat was formerly underlaid. Since the peat soils in the Everglades area are underlaid with limestone rock or by sand over lime rock, the need for caution in their unnecessary exposure is readily seen."

SUBSIDENCE OF ORGANIC SOILS IN THE UPPER EVERGLADES REGION OF FLORIDA

John C Stephens[1] and Lamar Johnson[2]

All organic soils lose surface elevation or subside when drained. This loss apparently continues as long as the lands are drained. The Florida Everglades, which contains the largest known body of organic soils in the world, has lost as much as 6 to 7 feet of soil in the Lake Okeechobee area since 1912. The Fens of England contain deep peat soils which have been under pumped drainage for over 100 years. They have lost approximately one inch per year on the average (1).[3] In central California, about 200,000 acres of tule peat has been in use for many years with an average recorded loss of approximately two inches per year.

The Everglades originally contained about 2,500,000 acres of organic soils but much of these are now very shallow and the deeper peat which now remains in the Upper Everglades comprises the main body of potential agricultural land in the Everglades area. This soil is particularly valuable for agricultural use and lies within an area containing approximately one thousand square miles, which has been designated as "The Everglades Agricultural Area" in the comprehensive Federal Flood Control plan for Central and Southern Florida. The soils within the boundary of this area have lost approximately forty percent of their original volume in the last forty years since drainage operations began.

In making plans for the original drainage of the Everglades, apparently the main causes of subsidence were misunderstood. The original shrinkage of the peat due to drainage was considered, but the continuing losses by slow oxidation in drained peat were not taken into account. Had the true nature and causes of subsidence losses been fully understood in the earlier days, the original plans might have been modified so as to have saved a large portion of the waste which has occurred since that time.

The United States Department of Agriculture has made continuing studies on the nature and rate of soil subsidence in the Everglades since 1916. From these and other studies the nature of soil subsidence has been more definitely ascertained. The purpose of this report is to sum up progress made to date so that the latest information on the subject will be readily available to those interested in the development of the peat and muck lands in the Upper Everglades area

These investigations can be divided into three main parts. First, studies were made by running profiles at periodic intervals on established subsidence lines. These studies give the rates of subsidence that have occurred under the existing conditions. Second, studies were made on water table plots under conditions of controlled water levels. These have established the effect of water levels on subsidence losses by oxidation, helped determine the effect of

[1] Research Project Supervisor, Everglades Project, Soil Conservation Service.

[2] Assistant Chief Engineer, of the Central and Southern Florida Flood Control District, and the Everglades Drainage District.

[3] Figures in parentheses refer to "Literature Cited."

different water levels on the growth of various crops, and have established a scale of minimum rates of subsidence which can be expected in cropped lands under conditions of controlled water levels. Third, original levels from early surveys were compiled and compared with more recent surveys to determine the total subsidence loss over the whole of the Upper Everglades area.

These studies show the rate of soil loss depends mostly upon depth to the water table; but, under equivalent conditions of drainage, the virgin peats subside at a slightly higher rate than cultivated peats, and that the undeveloped peat areas in the Upper 'Glades are suffering severe losses. Thus it seems that to insure fullest returns from the remaining soils for the next 50 years, an adequate water control system should be developed for the area as rapidly as practicable that will maintain optimum water levels and make possible the maximum production of food and fiber at minimum subsidence rates.

HISTORY OF SUBSIDENCE STUDIES

In order to secure more definite information on the rate and amount of subsidence of organic soils in Florida following drainage, the United States Department of Agriculture began the location of profile lines over selected peat and muck areas within the State during the year 1915. This work was begun by Charles W. Okey, under the direction of S. H. McCrory, Chief of Drainage Investigations, Bureau of Public Roads. In 1931, drainage investigations were transferred to the Bureau of Agricultural Engineering, and again in 1939 to the Soil Conservation Service following reorganization within the Department of Agriculture. Since 1931, the subsidence investigations have been carried on under the direction of Lewis A. Jones, Chief, Division of Drainage and Water Control, Soil Conservation Service.

Since 1933, subsidence and other studies relative to water control for agricultural lands in the Everglades have been conducted under a cooperative agreement between the Agricultural Experiment Station of the University of Florida and the Soil Conservation Service. In 1949, a Memorandum of Understanding between the Everglades Drainage District, the Central and Southern Florida Flood Control District, the Florida Agricultural Experiment Station, and the Soil Conservation Service was put into effect so that investigations since that date have been made in mutual cooperation with all these agencies.

The first profiles were run over the subsidence lines in 1916 and have been re-run at regular intervals thereafter. Additional lines were later established at the Everglades Experiment Station and around Lake Okeechobee to assist in a more comprehensive study. In April 1936, a mimeographed bulletin (2) describing the results of these studies up until that date was published.

In 1934, water table plots were installed at the Everglades Experiment Station near Belle Glade and the subsidence studies extended on a field where the depth of the water table and other factors could be closely controlled and observed. These investigations continued into 1943 and gave data on subsidence taking into consideration such factors as depth of water table, absence of fire, bacterial activity, soil compaction, soil temperature, and type of culture. In November 1942, a bulletin (3) containing a brief summary on these investigations prior to that date was published by the State Agricultural Experiment Station. These investigations are also described in the various Annual Reports published by the Agricultural Experiment Station of the University of Florida, Gainesville, Florida, and in reports by Clayton (4) and Neller (5).

From early surveys, the elevation of the surface of the Everglades has been obtained prior to any substantial drainage and subsidence. The earliest profiles made across the Everglades were from levels run by the Office of Experiment Station, United States Department of Agriculture. This work began in 1906 when levels were run from Fort Myers up the Caloosahatchee River to Lake Okeechobee. From a point on this survey, an additional line was continued in a southerly direction along the west edge of the Everglades to Brown s Store. Simultaneously, another party ran from Fort Myers southeasterly along the trail to Brown's Store, where the two lines of level were "tied" and the accuracy checked. From Brown's Store a line of levels was continued eastward across the organic soils of the Everglades to a point near Pompano where it connected with another line run from Atlantic tidewater elevation to check the accuracy of the levels. These and other early surveys are described in Senate Document 89 (6). About 1912, levels were run by the Everglades Drainage District along the location of the major drainage canals leading from coastal tidewater to Lake Okeechobee.

A topographic map showing surface elevations was prepared by the Everglades Drainage District compiled from surveys made about 1925. By this time considerable subsidence was found to have occurred along the canals as compared to original conditions in 1912, and the problem of soil loss was already receiving attention from many of those interested in the agriculture of the Everglades (7).

A contour map covering the area of organic soils was prepared by the Soil Conservation Service from topographic surveys made during the period between 1939 to 1942. This map resulted as a part of the intensive investigations made by the Everglades Project of the Soil Conservation Service under a specific appropriation by Congress to conduct research and demonstration work for soil conservation in the Everglades Region. These investigations included topographic surveys, soil conservation surveys to determine the various types of land and their capabilities, and sub-surface investigations of the rock structure and ground water as related to water control in the soil. In connection with the sub-surface investigations, a map showing the approximate contours on the rock surface under the organic soils in the Everglades Region was prepared. These investigations are described in Bulletin 442 (8) published in 1948.

In 1950, profiles and soil soundings were made by the Corps of Engineers over the proposed levee and canal locations in the flood control plan for the Everglades. The recent soil depth and surface elevations for the Everglades Agricultural Area were determined from this work.

By super-imposing surface contour maps prepared from the 1912, 1925, 1940 and 1950 surveys over the rock contour map, the depths of the organic soils in the Upper Everglades was obtained for each date. It was found that the soil losses were greatest near the arterial drainage canals and that in consequence "valleys" had been formed adjacent to them. However, even in areas remote from the immediate drainage influence of the canals, it was found that lands not sufficiently drained for development had nevertheless suffered severe losses. This is presumed to be due to the slow bleeding away of water by the canals as well as the diversion of surplus water in Lake Okeechobee to the Atlantic and Gulf. In early days, the overflow from the Lake drained into the Everglades during wet periods.

The organic soils of the Upper Everglades agricultural area have been divided into four types which have been described in detail in Bulletin 442 (8). These are Okeechobee muck, known locally as "custard apple"; Okeelanta peaty muck, or "willow and elder"; Everglades peaty muck; and Everglades peat, or "sawgrass land."

All the organic soils are dark brown to black in color. They were formed under marsh or swamp conditions by the partial decay of plant materials, with some admixture of mineral material in the case of the muck. Peat consists of 65 percent or more of organic plant remains, with a correspondingly smaller percentage of mineral matter. Muck contains 25 to 65 percent of organic matter mixed with sand, silt, and clay (9). Peaty muck in this area is usually a thin layer of peat over muck, or interstratification of peat and muck as in the instance of Okeelanta peaty muck. The peat and muck soils differ from each other in the kind of plant material from which they were formed, in depth, and in the nature of the underlying material. These soils may rest directly upon limestone or on an intermediate layer of sand or marl. These differences, especially depth of the peat or muck and the characteristics of the immediately underlying material, largely determine the capability of the land for farming and the economic feasibility of the establishment of adequate water control.

Okeechobee muck is a nearly black mixture of organic material and fine mineral soil that may be as much as 4 feet deep, underlain by brown fibrous peat. Deeper alternations of peat and muck layers may be present. An area of approximately 32,000 acres of this type soil is contained within the Everglades agricultural area occupying a belt surrounding the eastern and southeastern margin of Lake Okeechobee. This soil supported an original growth of custard apple trees, hence, the local name of "custard apple muck" for the soil type. It was early recognized as the best of the soils in the area and supported the earliest agriculture around the Lake. The organic portion of the soil appears to have been formed from the remains of succulent aquatic water plants which commonly grow in deep water, while the mineral content is probably due to its close proximity to the Lake and the deposition of fine sediment during overflows. The ash or mineral content varies from 35 to 70 percent of the oven-dry weight and the density is higher than the other organic soils in the area.

Okeelanta peaty muck consists of 6 to 18 inches of finely fibrous, well decomposed organic matter over a layer of black plastic muck which contains from 15 to 35 percent of mineral matter, and resembles Okeechobee muck. It borders the Okeechobee muck on the south and east and originally supported a growth of willows and elders. There are approximately 26,000 acres of this soil type within the area. It lies directly over hard limestone and most if it is still over 5 feet deep. In many areas cultivation has now entered into the top plastic layer.

Everglades peaty muck contains somewhat less mineral material than Okeelanta peaty muck or from 10 to 15 percent. It is usually lacking in the sub-surface layer of black plastio muck and the surface layer rests on brown, fibrous feltv peat, although some of it grades towards Okeelanta peaty muck. The total area is approximately 35,000 acres of which nearly one-third is underlain by sand.

By far the most extensive type of organic soil in the area is Everglades peat, the soil of the broad sawgrass plains, which occupies approximately 540,000 acres within the Everglades Agricultural Area. The upper 6 to 18 inches is an almost black, finely fibrous peat which contains from 8 to 15 percent mineral matter. The subsoil is a brown, undecomposed, finely fibrous peat which rests on the underlying rock, sand, or marl. It has been formed mainly from sawgrass material. Originally the entire profile was a brown, fibrous mass in which the partially decomposed sawgrass roots were readily distinguished. The roots are predominantly aligned in a vertical position which results in a soil structure that permits rapid movement of water vertically but more slowly laterally. After drainage the exposed layer becomes oxidized and weathered which gradually transforms the top soil into a black oxidized condition. When cultivated, the top layer changes into an amorphous mass, the density increases, the color darkens, the seepage rate decreases, and the top soil is transformed into a mucky condition. The saturated peat is slightly heavier than water, and when drained the water retained is equal to approximately three-fourths the total weight of the field sample. After a period of cultivation the density of the upper 18 inch layer of the soil will approximately double that of the underlying material; the oven-dry weight increasing from about 8 lbs. to 16 lbs. per cubic foot. This increase in density is accompanied by a corresponding decrease in volume; however, in subsidence of this nature there is little loss of actual soil material; the loss in surface elevation being due to compaction and structural change.

Northeast of West Palm Beach Canal from Lake Okeechobee to Twenty-Mile Bend is an old slough in which the peat is believed to have been originally formed partly from water plants and was of a less dense structure than the Everglades peat. However, as a result of partial drainage for a number of years, it has become denser and can scarcely be distinguished from Everglades peat. The deepest soils in the area occur along this old slough.

CAUSES OF SUBSIDENCE

Loss of surface elevation or subsidence accompanying drainage of organic soils in the Everglades is due mainly to slow oxidation from biochemical action, to burning, and to mechanical compaction. Minor losses have occurred from shrinkage due to drying and loss of the buoyant force of water in the drained layer. Wind and water erosion has had little effect in this region.

The most serious and continuing loss is due to slow oxidation caused by the action of aerobic bacteria. These organisms are active only in the aerated zone and the rate at which the soil subsides due to their action depends primarily upon the depth to the water table; hence the higher the water table, the less this loss. Such bacteria belong to the saphrophytes which live on dead or decaying organic matter and begin their assault upon the peat when the water level falls appreciably below the surface. In the presence of oxygen they convert the organic matter into carbon dioxide gas. This gas has been collected and measurements show that the amount of gas evolved from the peat soil was directly related to the rate of loss of soil mass (10). Temperatures seem to regulate the activity of the bacteria and it appears that the subtropical climate of the Everglades increases the rate of soil loss as compared to losses for organic soils in the northern states under conditions of similar drainage. There also seems to be little doubt that the rate of oxidation is related to the amount of air movement within the drained zone. It has been noted that whenever the soil surfaces are sealed in the peat soils, the subsidence materially decreases. Thus, paved roadways and concrete tennis courts

in the Everglades which have been constructed for a period of 10 years or more now stand a foot or more higher than the immediately surrounding lands.

Loss in elevation is most rapid during the first five years following drainage and cultivation. The virgin Everglades peat is about the same density from top to bottom prior to drainage, but after 10 years of farming the top 18 inches increases in density to about double that of the peat beneath. A large part of this loss is due to compaction during farming operations. If virgin peat is drained but not put to use, the samples taken from these unused lands show the top aerated zone has developed a spongy texture and there has been an actual loss of soil mass greater than that on adjacent farmed areas (11). Whenever such land is later put to cultivation the loss in soil mass and in depth is greater than the adjacent farmed area provided they have had equal drainage. Thus, peat lands once drained should be put to use as soon as possible to achieve the maximum potential production and benefits.

Soils in the Everglades are also destroyed by burning. Loss from fire is more spectacular and arouses public interest far more than the loss caused by natural oxidation; yet, in the long run, the relentless toll of the invisible hosts of organisms results in a much greater total soil loss than from fire. Sawgrass fires sweep over the undeveloped 'Glades almost annually. They do little permanent soil damage until dry periods when the water table sinks from 18 to 24 inches or more below ground and the peat becomes dry enough to burn. Once this occurs, the heat of combustion dries out the moisture from adjacent soils and they become very difficult to extinguish. In the more remote areas of the Everglades they may reach such proportions as to defy man's attempts to control them and continue to burn until heavy rains occur. In farmed lands, and accessible locations, such fires are usually discovered early and extinguished before they can do much damage.

"Blowing", or the removal of soil by wind erosion, which may be serious in other localities, accounts for practically no soil loss in the Everglades region since this area is so large that soil blown from one field is simply deposited on surrounding fields.

SUBSIDENCE LINE STUDIES

The following graphs with the accompanying descriptions have been prepared from information obtained by periodic leveling over the various profile lines and show the lowering of ground surface with respect to time. In these cases, it is impossible to determine what portion of the total loss is due to each of the causes mentioned in the preceding discussion, but it appears certain that slow oxidation of the drained peat was the principal cause. Some elevations of the water table were obtained but the average elevations and fluctuations are not known. The results show only the total losses from all causes.

Figure 1. (Line 980 ft. north of Bolles Canal at Okeelanta.)

This line is located in an area in which the soil is predominantly Okeelanta peaty muck and had gravity drainage prior to 1942 at which time pumps were installed. The west half of the line was in fallow prior to 1936 while the east half was in cultivation from one to three year periods prior to 1922. Sporadic plantings of truck crop followed the installation of pumps in 1942 until the present. This area has been burned over several times, but a comparison of land surface elevations with adjacent unburned lands shows that the loss in elevation due to fires is only a small part of the total loss in elevation.

This line shows the relative rapid initial subsidence, the decreasing rate under gravity drainage as the ground surface sank and drainage was impaired, and the consequent increase in subsidence rates after the installation of pumps in 1942

Figure 2 (Line below South Bay lock, near One-Mile Post on North New River Canal.)

This line is located in an area in which the soil is Okeelanta peaty muck and had gravity drainage prior to the installation of pumps in 1927 by the South Florida Conservancy District. The land in this area was not used for crops until after the installation of pumps. Since that date, it has been generally planted to cane and truck crops. The normal pattern of very fast sinking of the surface with initial drainage, a leveling off as gravity drainage decreased, the increase in rate with increased drainage due to pumping installations, and the steady loss of surface elevation thereafter is seen.

Figure 3. (Line near south shore of Lake Okeechobee at South Bay.)

This line is located in Everglades peaty muck and had gravity drainage prior to 1927 at which time pumps for the area were installed by the South Florida Conservancy District. Approximately half of this line was in cultivation from 1914 to 1928, and nearly all of the area traversed by the line has been in cane and truck crops since 1927. As far as is known, none of the land in this area has ever been seriously burned. The early initial subsidence loss, the leveling out period during the latter phase of gravity drainage, the increase in subsidence due to pump drainage, and the relatively consistent losses afterward are illustrated by this line.

Figure 4. (Line on lawn at Experiment Station 85 ft. east of pump ditch. Station 0 + 50 to 3 + 50.)

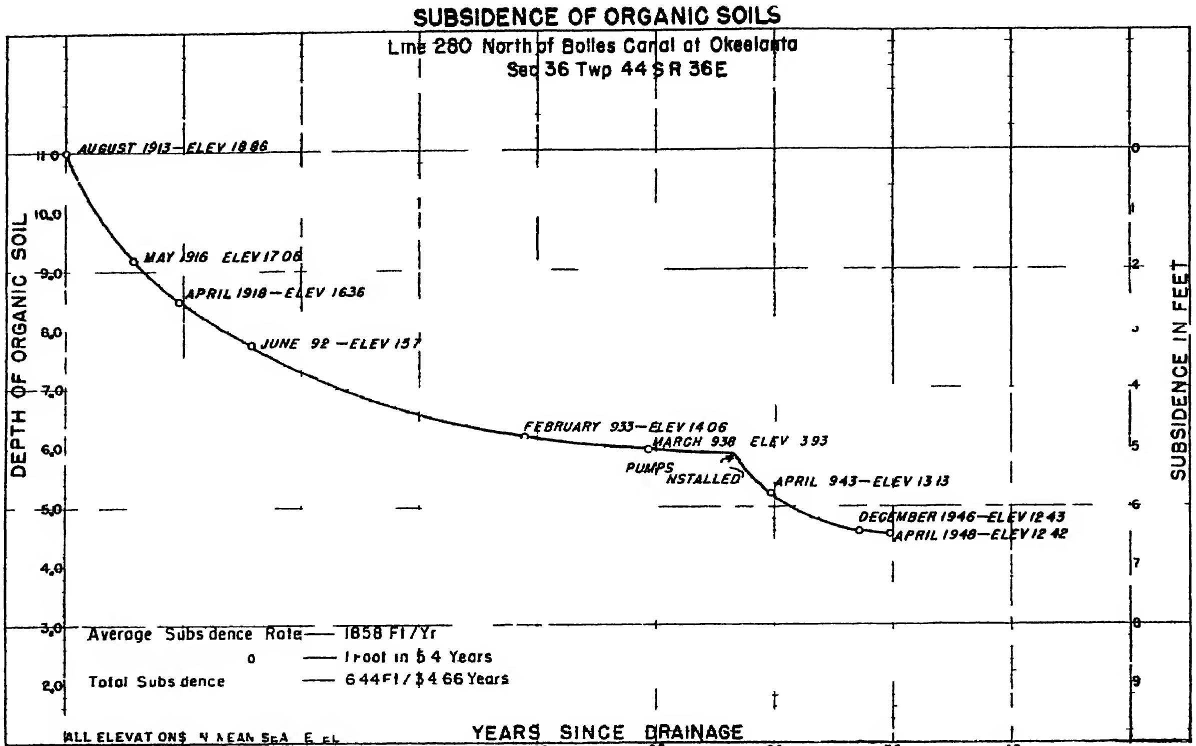
This line is located at the Everglades Experiment Station on Everglades peat covered with a thick sod of St. Augustine grass and has had controlled drainage for the entire period of observation. The area was covered with grass approximately 14 years prior to establishment of the subsidence line. It has not been compacted by grazing or rolling, and soil samples show that a spongy, open textured structure has developed in the aerated zone. Loss of soil mass has therefore been more than that indicated by loss of surface elevation as shown on the graph.

Figure 5. (Line on lawn at Experiment Station 95 ft. west of front porches on residences. Station 1 + 75 to 6 + 25.)

This line is located on Everglades peat covered with a thick sod of St. Augustine grass and has had controlled drainage for the entire period of observation. This area was also covered with grass for approximately 14 years prior to establishment of the subsidence line. For all practical purposes, this line duplicates that shown in Figure 4, and density samples show the same open, spongy texture as described for that line.

Figure 6. (Well line "B" at Experiment Station. Station 0 + 00 to 4 + 75, exclusive of ditch banks.)

This line is located at the Everglades Experiment Station on Everglades peat. The northern half has been in pasture and the southern half generally planted to truck crops. The area has had controlled drainage for the period of observation and had been planted to truck crops for approximately 14 years prior to establishment of the subsidence line. The water table for this line has been comparable to that for the lines shown in Figures 4 and 5. It should be noted



Figur howing the relative rapid initial subsidence the decreasing rate nder gravity dr inig a th gro nd rface sank and drainage was impaired and the consequent in rea in subsidence rates after pumped drainage on Okeelanta peaty muck

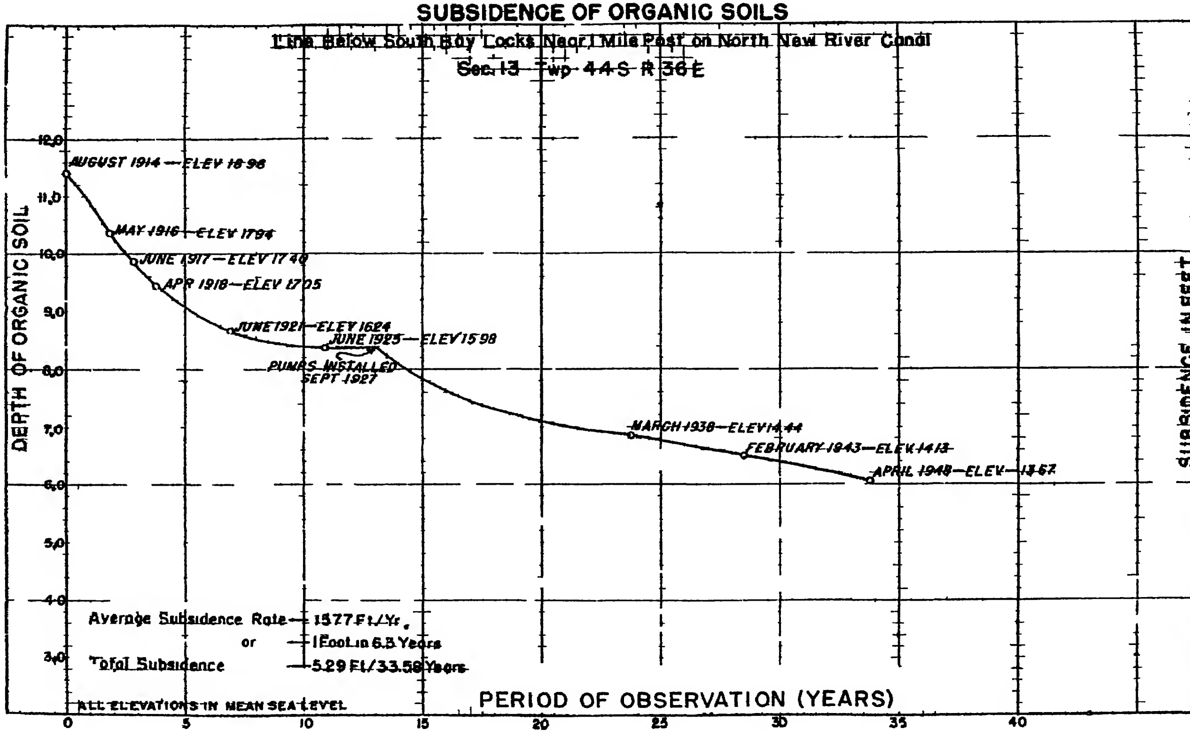


Figure ? The normal pattern of fast sinking of the surface with initial drainage, a leveling off as gravity drainage decreases, an increase in rate with increased drainage due to pumping, and the steady loss of surface elevation thereafter is seen. Soil is Okeelanta peaty muck.

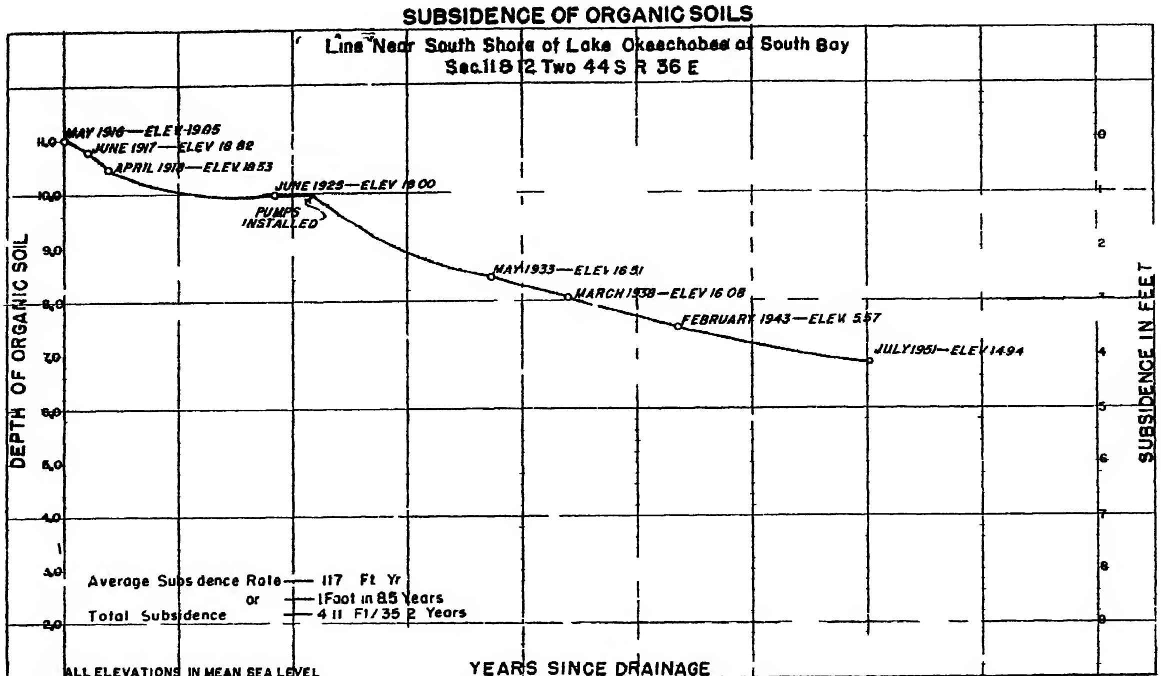


Figure 3 The normal subsidence pattern is again illustrated by this graph Soil is Everglades peaty muck As far as is known none of the land in this area has ever been seriously burned

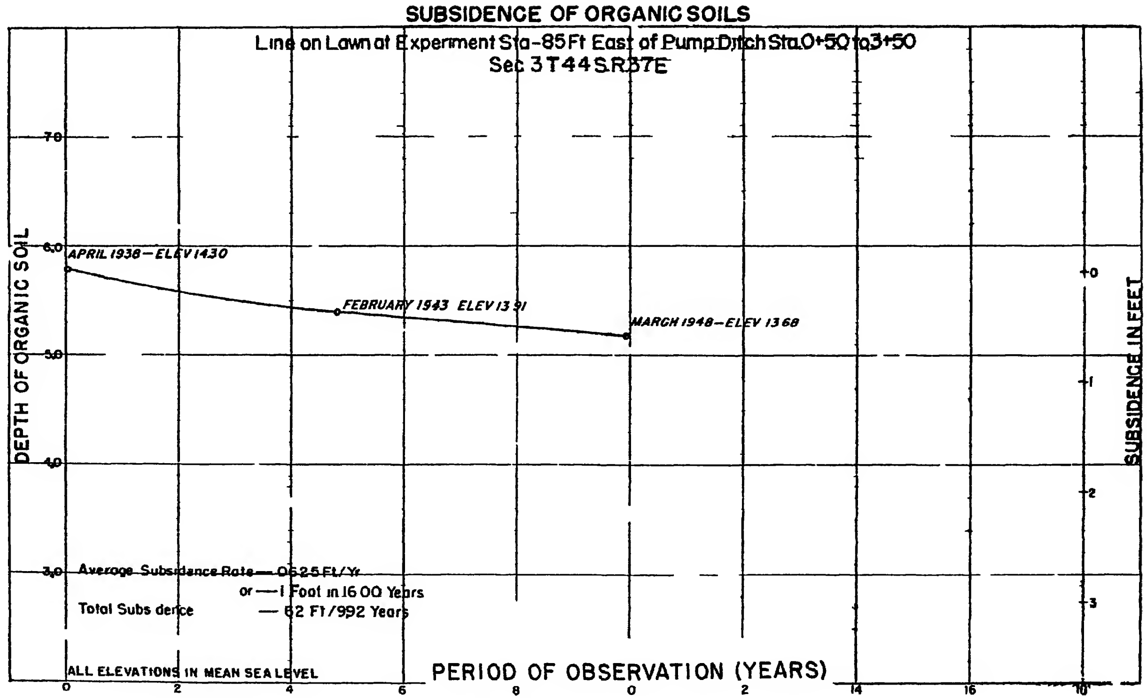


Figure 4 Subsidence on ungrazed sod Soil samples taken in the upper layer show that a spongy open textured layer has developed in the drained zone with considerable loss of soil mass

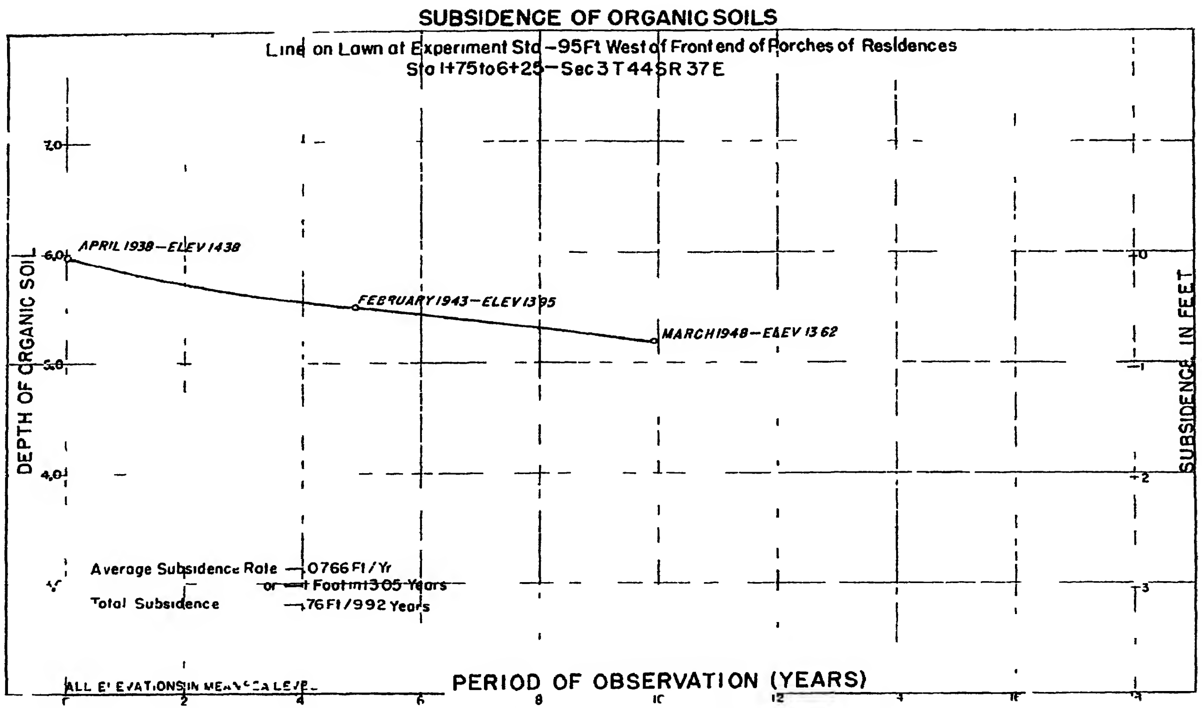


Figure 5 This line, for all practical purposes, duplicates that shown in Figure 4 Density samples show the same spongy texture. There are some indications that subsidence rates on sod lands are reduced by grazing and compaction of the surface

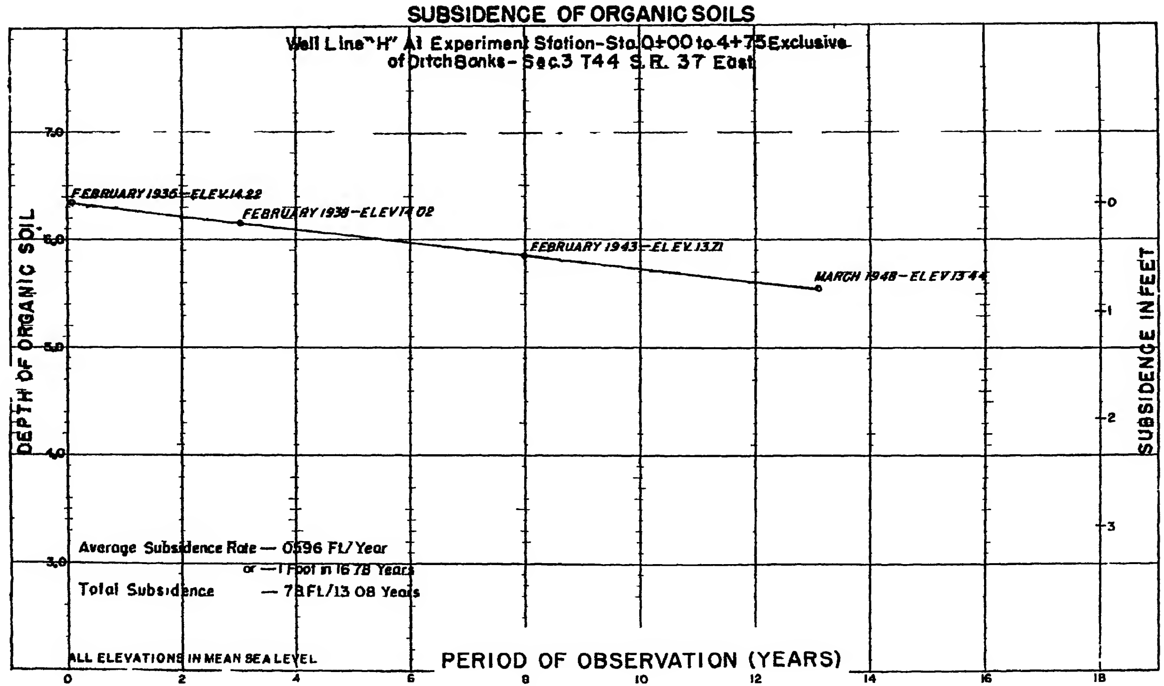


Figure 6 The water table for this line has been comparable to that of the two previous lines However, this land has been in truck crops and pasture Soil samples show that loss of soil mass is less than from the ungrazed sod areas

that the average subsidence rate along this line is slightly lower than for the two previous lawn lines Further the soil samples from this line showed increased density in comparison to these lines The sealing effect of cultivation on the cropped lands has apparently decreased the rate of loss of soil mass as compared to the uncultivated areas

Figure 7 (Well line A at Experiment Station)

This line is located in Section 10 at the Everglades Experiment Station on Everglades peat with virgin growth prior to 1940 The area received only fair drainage by perimeter ditches until 1940 when small farm laterals were dug The south half or Reach A", has been undeveloped and in sawgrass and elders during the period of observation The area traversed by the north half of this line, or Reach B , was undeveloped until January 1944 when it was planted and disced Lateral drainage ditches were dug in January 1945 The steady rate of subsidence along Reach A and the increased rate of subsidence along Reach B due to cultivation is illustrated by this line

Figure 8 (East line at Experiment Station)

This line is located on Everglades peat at the Everglades Experiment Station and was originally established in 1927, but original notes were lost The line as reestablished in 1934 is representative of land that has had its initial subsidence from cultivation and drainage It has been planted continuously to truck crops with controlled drainage for the period of observation, and possibly represents average subsidence conditions that prevail on lands planted to truck crops in the Everglades where flood fallow is not practiced

Figure 9a (Wedgeworth-Raoul Farms - North and South line Station 0 + 00 to Station 9 + 90)

This line is laid out at right angles to drainage laterals on Everglades peat soil that was in virgin sawgrass until 1938 The area was plowed disced and in cultivation from 1938 through November 1940 The area was converted to pasture between 1940 and 1943 and was in pasture through 1948

Figure 9b (Wedgeworth-Raoul Farms - North and South line Station 11 + 00 to 20 + 00)

This line is at right angles to drainage laterals on Everglades peat soil that was in sawgrass until 1937 The area was cultivated intensively for truck crops (celery and beans) through 1948

Figure 9c (Wedgeworth-Raoul Farms - East and West line Station 0 + 00 to 9 + 50)

This line is located on Everglades peat soils that was in virgin sawgrass until 1938 The area was plowed, disced and brought into cultivation with a fair degree of drainage from 1938 through November 1940 The area was converted to pasture between 1940 and 1943 and was in pasture through 1948

Figure 9d (Wedgeworth Raoul Farms - Station 10 + 50 to 23 + 00)

This line is located on Everglades peat soil that was under sawgrass with moderate drainage until 1937 The area was put into cultivation in 1937 for potatoes, in 1938 for potatoes and gladiolus, for celery in 1939 for celery and spring crop beans in 1940 to 1946, and was idle from 1946 to 1947 The

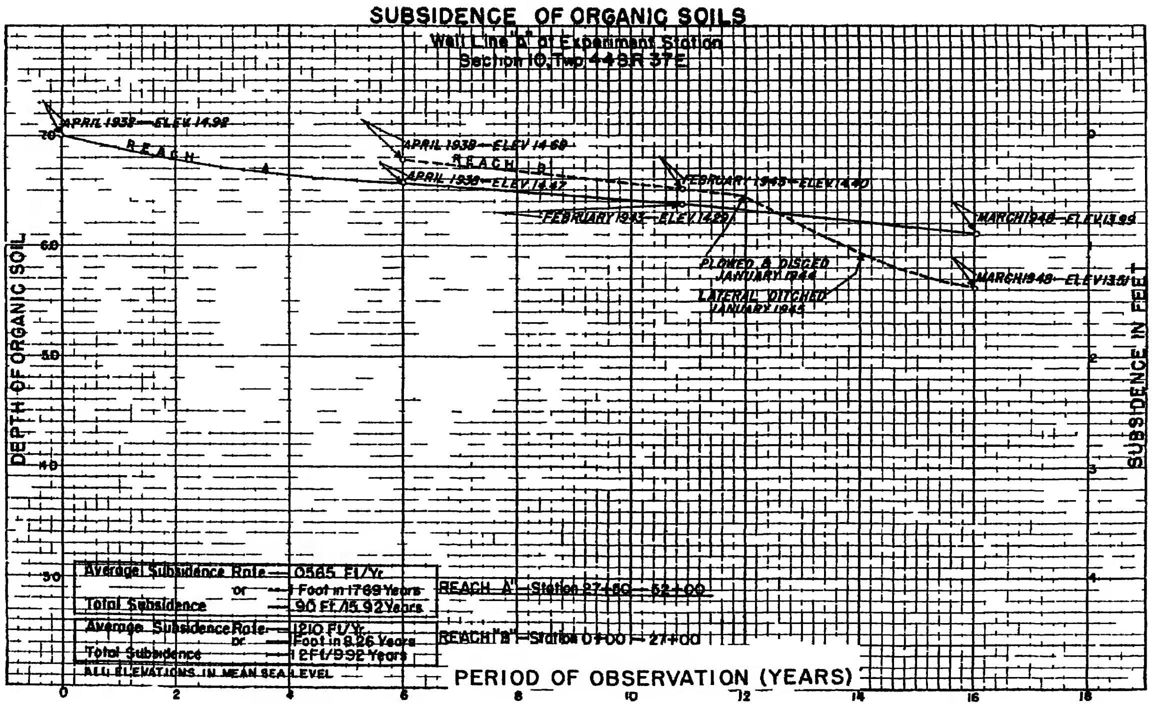


Figure 7 Reach A of this line has remained undeveloped and in sawgrass during the period of observation Reach B the north half of this line was undeveloped until 1944 when it was planted and disced The steady rate of subsidence along Reach "A and the increased rate of subsidence along Reach B due to initial cultivation is illustrated

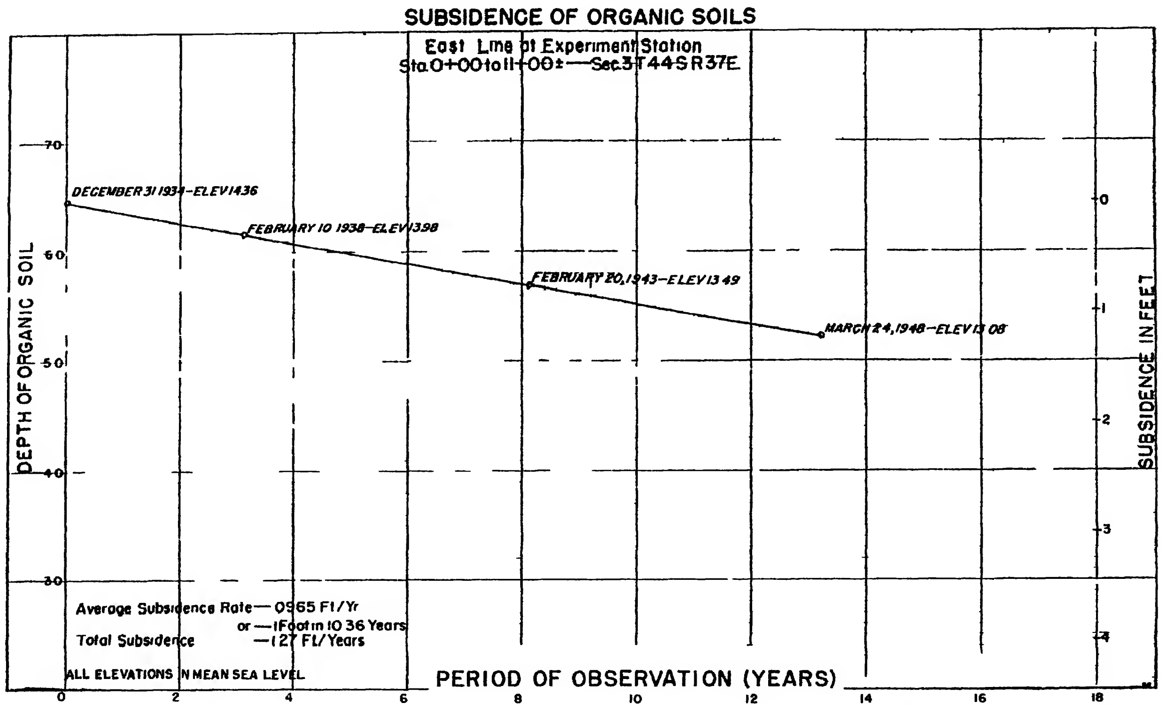


Figure 8 This graph is representative of subsidence on land that has already taken its initial loss from mechanical compaction This field has been planted to truck crops with controlled drainage at the Everglades Experiment Station since before 1934 The rate of subsidence has been steady at about one foot in 10 years

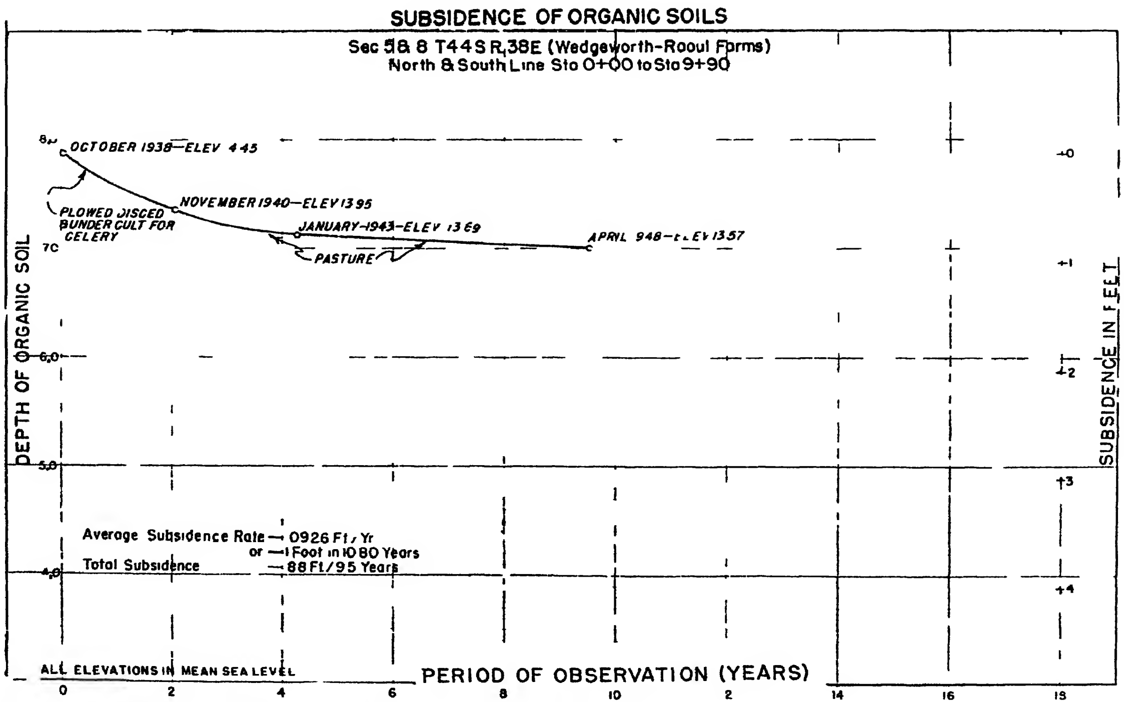


Figure 9a The following group of figures are significant in that they indicate that peat land in grazed pasture may subside slower than for similarly drained lands under other culture Compare figures 9a with 9b and 9c with 9d

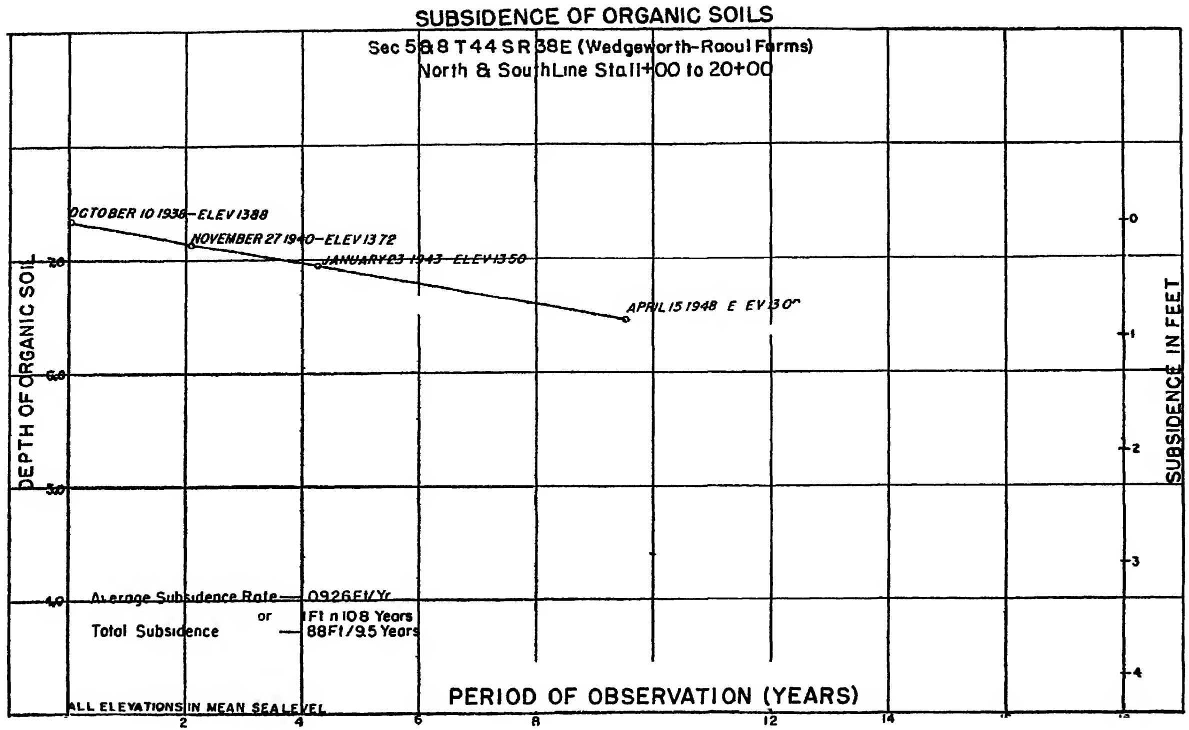


Figure 9b This land adjoins that represented in 9a but has been in truck crops continuously through 1948 whereas the other area was converted to pasture between 1940 and 1943 and remained so through 1948

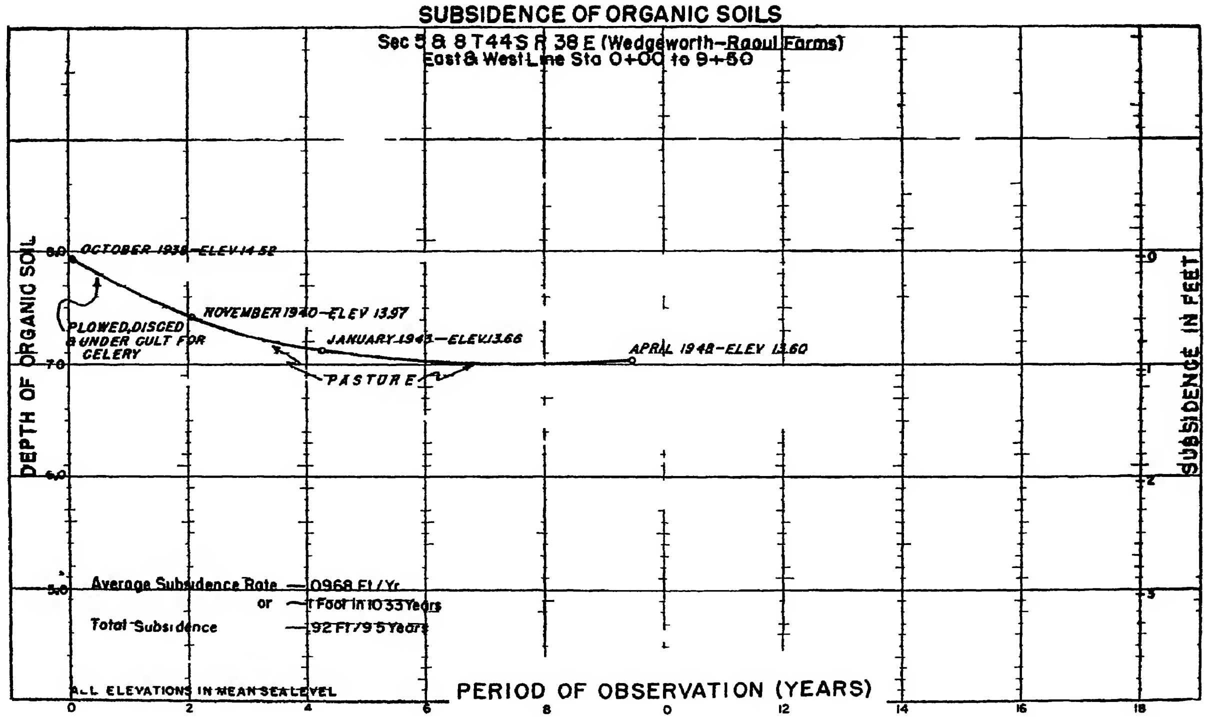


Figure 9c   This land was converted to pasture with a decrease in subsidence rate indicated thereafter   The adjoining land   Figure 9d   was kept in truck and subsidence continued at a steady rate

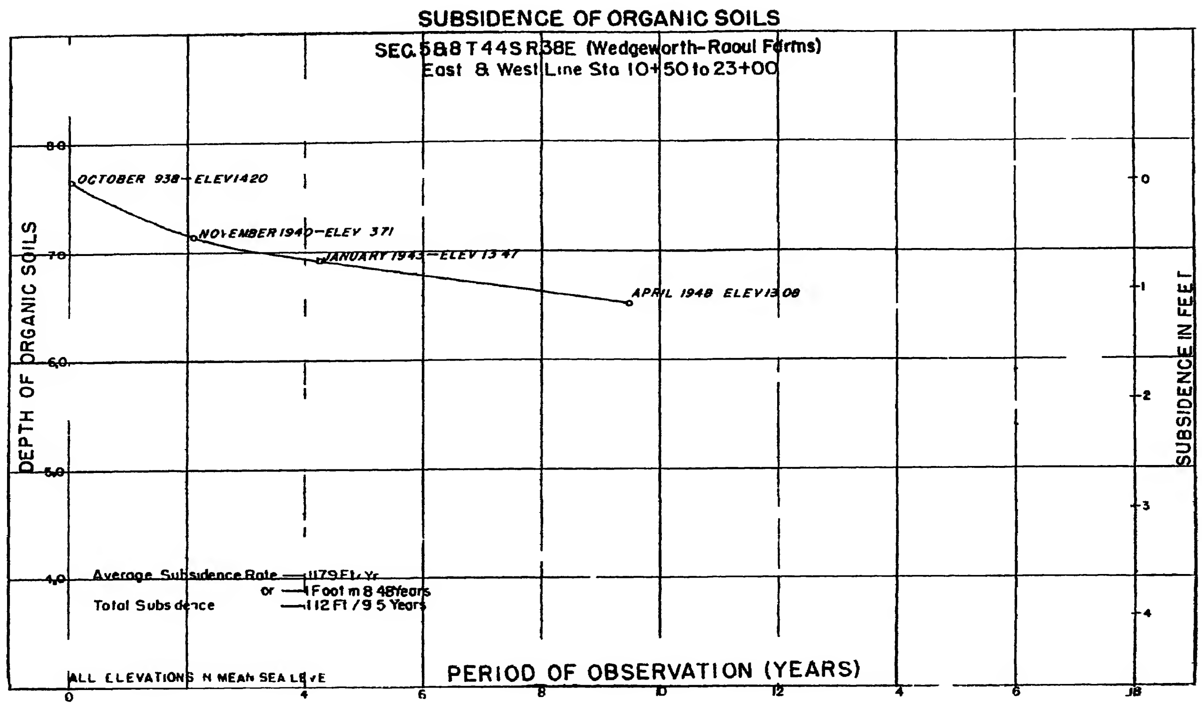


Figure 9d The period of observation on the preceding group of lines has been too short and density tests have not been made so there is as yet insufficient data to judge whether or not these grazed pasture lands will continue to subside at slower rates than the other lands

area wa n ative grass pasture lightly grazed from 1947 to present Compare Figures 9a against 9b and 9c against 9d It will be noted that when Lines A and C were put into pasture and grazed the subsidence rate decreased materially a compared to the adjacent reach which was in truck crops However the period of observation has been too short and density tests have not been made so that there is as yet insufficient data to judge whether or not this type culture may offer an effective means of reducing subsidence rates any appreciable extent

F g e ne at Liberty Point)

This line is located on Everglades peaty muck and the area it traverses had its initial subsidence prior to beginning of observation This line is believed representative of cane land with average water control

igure re at Davie Florida)

This line i located near Davie Florida and was laid out on Everglades peat over sand The area received drainage by one of the first pumping stations installed in the Everglades Region in 1913 Pumping was discontinued by the old Davie Dist ict about 1916 The completion of the Danie Cut off Canal shortly therea ter furnished sufficient gravity drainage and in 1920 this area was incorporated into the present Broward Drainage District From Station 14 ⁄ 0 to 0 ⁄ 00 all but 900 feet has been in cultivation for one or more seasons Since 1933 approximately 1 000 feet of the line has been embraced within an orange grove From Station 0 ⁄ 00 to 14 ⁄ 00 the line has been covered by a school yard and an abandoned orange grove and in many places along this portion of the line there are now areas of bare sand While not in the Everglades Agricultural Area this line is shown because it illustrates the fact that the subsidence of peat continues under drainage until the unde lying material is reached

P P ME AL STUDIES ON CONTROLLED WATER TABLE PLOTS

In 1934 at the Everglades Experiment Station a field of Everglades peat was divided into eight blocks each 100 x 240 feet These blocks were surrounded by a system of ditches and check dams whereby the water table could be controlled at any desired level under each block This was accomplished by means of two 1 000 gpm electrically driven pumps with automatic float controls which pumped the water from the block of the lowest water table to that of the highest from where it passed successively over check dams to each of the lower levels Both mole drains and tile drains were provided to aid in keeping levels as uniform as possible under each block Overhead spray irrigation was install d on two of the blocks to supply water by this method during dry seasons A ground water observation well and a recording ground water gage connected by underground tubing were installed on each block Figure 12 is a plan drawing showing the arrangement and layout of the water table field Each block was subdivided into three equal divisions and planted to different crops as shown on plots 4 and 5 Figure 12

In 1934 the blocks were uniformly cropped and the water level held at the same level under all blocks to determine field variability Precise levels were run over the entire field to obtain the average ground elevation of each block and the adjacent area The prescribed water levels were established in November 19

The purpose these experiments was to determine the effect of the water

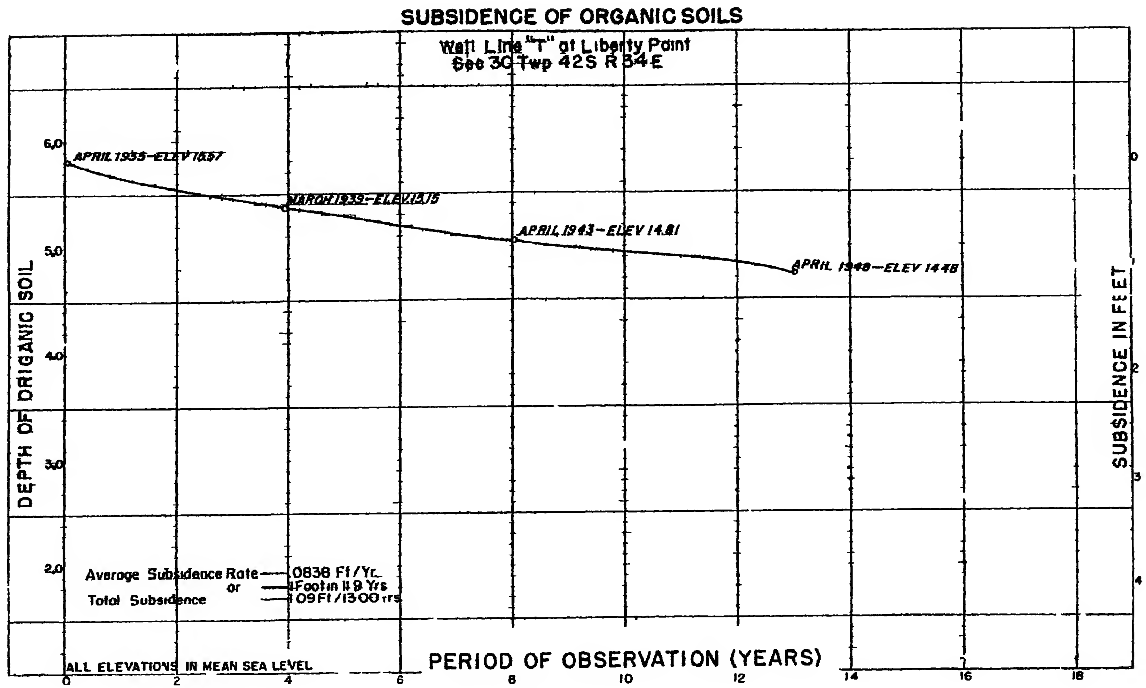


Figure 10 This graph shows loss of surface elevation typical of Everglades peaty muck lands planted to sugarcane The area was in cultivation prior to establishment of the profile line in 1935 and the average rate of soil loss has been about one foot in 12 years since that date

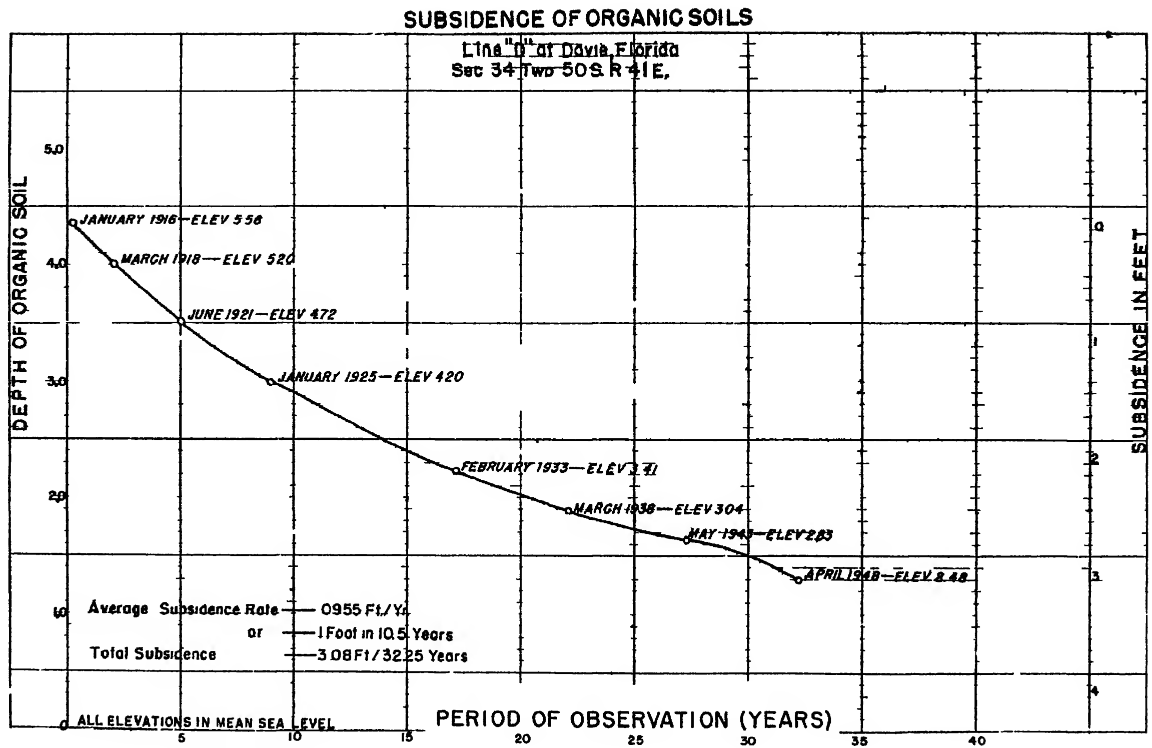


Figure 11   This line was originally laid out on Everglades peat over sand   In some places along portions of the line, the peat has entirely disappeared with only the bare sand exposed

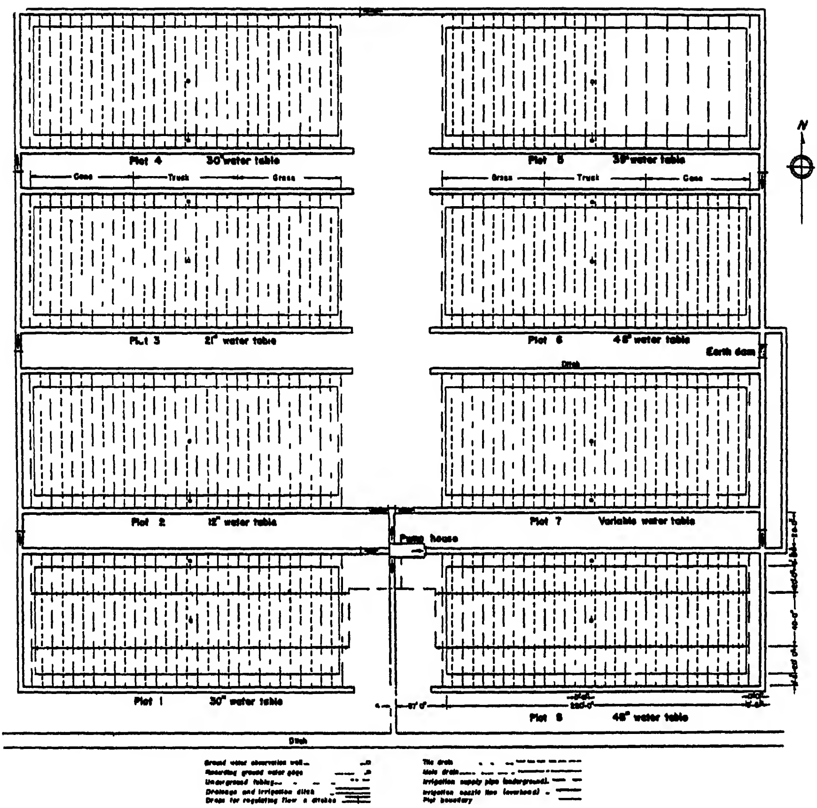


Figure 12 Showing the layout and arrangement of the field at the Everglades Experiment Station on which the experimental studies on controlled water table plots were conducted. One-third of each plot was planted to cane, to truck crops, and to grass as indicated. Water levels were held at various predetermined depths under each plot. Precise levels and soil analyses showed that loss of the peat soil depended almost directly upon the depth to the water table

table on the subsidence of peat under controlled conditions and to study the effect of different water levels on the growth of various crops. During the first two years the water tables were held at levels varying approximately 9 inches between plots and about 6 inches between plots for the remaining years. Overhead spray was used on plots 1 and 8 to raise the water levels during the dry part of the year and the water in the variable plot, No. 7, was raised to within 6 inches of the surface and quickly lowered once each week except during wet periods. These studies were concluded in early 1943 at which time the surface elevations had declined from 6 to 14 inches for the various blocks below their 1935 level.

Table 1 tabulates the results of the studies showing the relationship of subsidence to the depth of the water table.

It will be noted that the portion of the plots planted to cane subsided less than those portions used for truck and grass crops. However, Clayton (12) has stated that this difference may be accounted for by the relative densities of the upper portion of the soil on the different plots and that it is doubtful if there is any appreciable difference in the rate of subsidence for the crops grown. Levels in the blocks where the water table was to be maintained deepest could not be held at these predetermined depths because of inability to keep the levels lower after the surface subsided as can be seen by inspecting the decrease in average depth of water table from year to year for plot number 6, Table 1.

The significant and most important results from these studies are summarized by the graph, Figure 13, showing the average annual subsidence per year as compared to the average depth of the water table as compiled from the results shown in the last column of Table 1. This figure illustrates very strikingly that, disregarding the top few inches of soil, the *rate of subsidence is dependent upon the depth of water table.* The higher the water table, the less the loss of soil and vice versa.

Inasmuch as change in density, as well as loss in surface elevation must be measured to determine true soil loss, samples were obtained annually to determine the loss in soil weight and the increase in ash content of the soil layer above the water table. Equipment was also installed which provided for the collection of soil gasses which were analyzed for CO_2 gas, the by-product of biochemical oxidation. The methods used and results obtained have been described in detail by Neller (10) who showed that the rate of oxidation as indicated by the production of CO_2 depended strikingly upon the height of the water table. Neller's work corroborated that the predominant factor in loss of soil mass in organic soils is the depth to water table. Thus, for soil conservation, water levels should be held as high as is compatible with crop production and field accessibility.

The controlled water table experiments show that good farming and better controlled farm water levels can result in increased production of crops at higher water levels than that now generally maintained on cropped areas, with consequent decrease in the present rate of soil losses. A brief outline of the results of these experiments as reported in the Annual Reports of the Florida Agricultural Experiment Station indicates for truck crops a water table of from 18 to 25 inches is optimum. Celery seems to do best at an 18 inch water level, while most other vegetables, such as beans and potatoes, grow better at a water level of about 24 inches. Pastures have produced well on water levels of 18 inches and even less when once established. Corn seems

SUBSIDENCE ON CONTROLLED WATER TABLE PLOTS
EVERGLADES EXPERIMENT STATION
1936 THROUGH 1942

* ** * ** * ** * ** * ** * ** *

PLOT NO.	DIVISION	CULTURE	1936		1937		1938		1939	
			DEPTH OF W.T.	SUBSI-DENCE	DEPTH OF W.T.	SUBSI-DENCE	DEPTH OF W.T	SUBSI-DENCE	DEPTH OF W.T.	SUBSI-DENCE
1	East	Grass	2.24	0.14	1.93	0.13	1.88	0.11	1.82	0.09
	Center	Truck	2.29	.12	2.01	.10	1.96	.12	1.90	.11
	West	Cane	2.28	.15	2.05	.02	2.10	.04	2.07	.12
	Average		2.27	.14	2.00	.06	1.98	.10	1.93	.10
2	East	Grass	1.00	.08	0.94	.02	0.96	.01	0.99	.01
	Center	Truck	1.11	.04	1.04	.09	1.00	.06	1.01	.00
	West	Cane	1.13	.06	1.08	.01	1.13	.02	1.13	.09
	Average		1.08	.06	1.02	.04	1.03	.02	1.05	.03
3	East	Grass	1.58	.09	1.40	.04	1.44	.07	1.36	.06
	Center	Truck	1.69	.04	1.52	.07	1.55	.08	1.47	.03
	West	Cane	1.78	.07	1.63	.02	1.71	.02	1.63	.10
	Average		1.68	.07	1.52	.05	1.56	.05	1.49	.07
4	East	Grass	2.25	.12	1.90	.07	1.85	.10	1.63	.14
	Center	Truck	2.34	.12	2.00	.07	1.96	.09	1.94	.13
	West	Cane	2.42	.07	2.13	.02	2.12	.06	2.16	.06
	Average		2.34	.10	2.02	.05	1.98	.09	1.98	.11
5	East	Cane	2.54	.15	2.66	.03	2.73	.06	2.57	.09
	Center	Truck	2.50	.17	2.57	.12	2.55	.15	2.29	.19
	West	Grass	2.55	.20	2.60	.12	2.57	.15	2.35	.13
	Average		2.53	.18	2.61	.08	2.62	.12	2.40	.14
6	East	Cane	3.21	.19	3.04	.05	3.06	.12	2.88	.07
	Center	Truck	3.20	.22	2.96	.15	2.89	.21	2.61	.18
	West	Grass	3.23	.25	2.96	.18	2.90	.16	2.68	.12
	Average		3.21	.21	2.98	.13	2.95	.16	2.72	.13
7	East	Cane	3.11	.20	2.83	.04	2.86	.14	2.84	.07
	Center	Truck	3.11	.23	2.75	.18	2.71	.14	2.66	.14
	West	Grass	3.13	.26	2.78	.13	2.75	.15	2.69	.16
	Average		3.12	.23	2.79	.12	2.78	.14	2.74	.13
8	East	Cane	3.23	.23	2.88	.08	2.91	.17	2.76	.08
	Center	Truck	3.15	.2[illegible]	2.78	.19	2.76	.19	2.57	.10
	West	Grass	3.09	.22	2.73	.14	2.75	.15	2.58	.13
	Average		3.15	.2[illegible]	2.80	.14	2.80	.18	2.63	.10
Intervening Months Between Measurements			13.5		12.75		11.5		13.0	

NOTE ALL MEASUREMENTS ARE IN FEET

SUBSIDENCE ON CONTROLLED WATER TABLE PLOTS
EVERGLADES EXPERIMENT STATION
1936 THROUGH 1942
(continued)

PLOT NO.	DIVISION	CULTURE	1940		1941		1942		AVERAGE		
			DEPTH OF W.T.	SUBSI-DENCE	DEPTH OF W.T.	SUBSI-DENCE	DEPTH OF W.T.	SUBSI-DENCE	DEPTH OF W.T.	* ANNUAL SUBSIDENCE	* TOTAL SUBSIDENCE 1936-1942
1	East	Grass	1.77	0.14	1.77	0.14	1.59	.24	1.86	.1338	.99
	Center	Truck	1.78	.23	1.78	.06	1.65	.23	1.91	.1311	.97
	West	Cane	2.00	.13	2.02	.12	1.85	.24	2.05	.1054	.78
	Average		1.86	.17	1.86	.11	1.69	.23	1.94	.1230	.91
2	East	Grass	0.98	.10	0.91	.11	1.23	.13	1.00	.0622	.46
	Center	Truck	1.00	.10	.95	.05	1.31	.13	1.06	.0635	.47
	West	Cane	1.13	.01	1.12	.05	1.47	.16	1.17	.0486	.36
	Average		1.03	.07	1.00	.07	1.34	.14	1.08	.0581	.43
3	East	Grass	1.40	.16	1.37	.12	1.34	.16	1.41	.0946	.70
	Center	Truck	1.52	.17	1.48	.14	1.45	.14	1.52	.0905	.67
	West	Cane	1.68	.09	1.72	.07	1.69	.20	-.69	.0770	.57
	Average		1.54	.13	1.52	.12	1.49	.16	1.54	.0878	.65
4	East	Grass	1.90	.16	1.83	.23	1.66	.20	1.89	.1365	1.01
	Center	Truck	1.97	.23	1.89	.16	1.76	.20	1.98	.1351	1.00
	West	Cane	2.29	.11	2.24	.21	2.10	.19	2.21	.0973	.72
	Average		2.05	.16	1.99	.20	1.84	.20	2.03	.1230	.91
5	East	Cane	2.58	.09	2.56	.12	2.37	.31	2.57	.1149	.85
	Center	Truck	2.21	.18	2.11	.18	1.93	.23	2.31	.1649	1.22
	West	Grass	2.29	.20	2.17	.20	1.97	.27	2.36	.1716	1.27
	Average		2.36	.15	2.28	.17	2.09	.27	2.41	.1500	1...
6	East	Cane	2.71	.11	2.67	.15	2.35	.28	2.85	.1311	.97
	Center	Truck	2.33	.21	2.23	.16	1.93	.24	2.59	.185:	1.37
	West	Grass	2.44	.18	2.35	.19	2.02	.27	2.65	.1824	1 35
	Average		2.49	.16	2.41	.17	2.10	.27	2.69	.1662	1.23
7	East	Cane	2.76	.08	2.73	.10	2.58	.32	2.82	.1284	95
	Center	Truck	2.49	.17	2.38	.18	2.27	.17	2.62	.1635	1.21
	West	Grass	2.53	.14	2.41	.23	2.23	.25	2.65	.1784	1.32
	Average		2.59	.13	2.50	.17	2.35	.25	2.70	.1581	1.17
8	East	Cane	2.63	.12	2.50	.16	2.36	.24	2.75	.1473	1.09
	Center	Truck	2.4.	15	2.28	.14	2.16	23	2.59	.1635	1.21
	West	Grass	2.39	.19	2.22	16	2.07	.26	2.55	1689	1 25
	Average		2.47	.15	2.34	.15	2.20	.24	2.63	158.	1.17
Intervening Months Between Measurements			1..5		12 25		14 5		TOTAL MONTHS -- 89		

NOTE: ALL MEASUREMENTS ARE IN FEET

* CALCULATED FROM 1936 ELEV MINUS 1942 ELEV

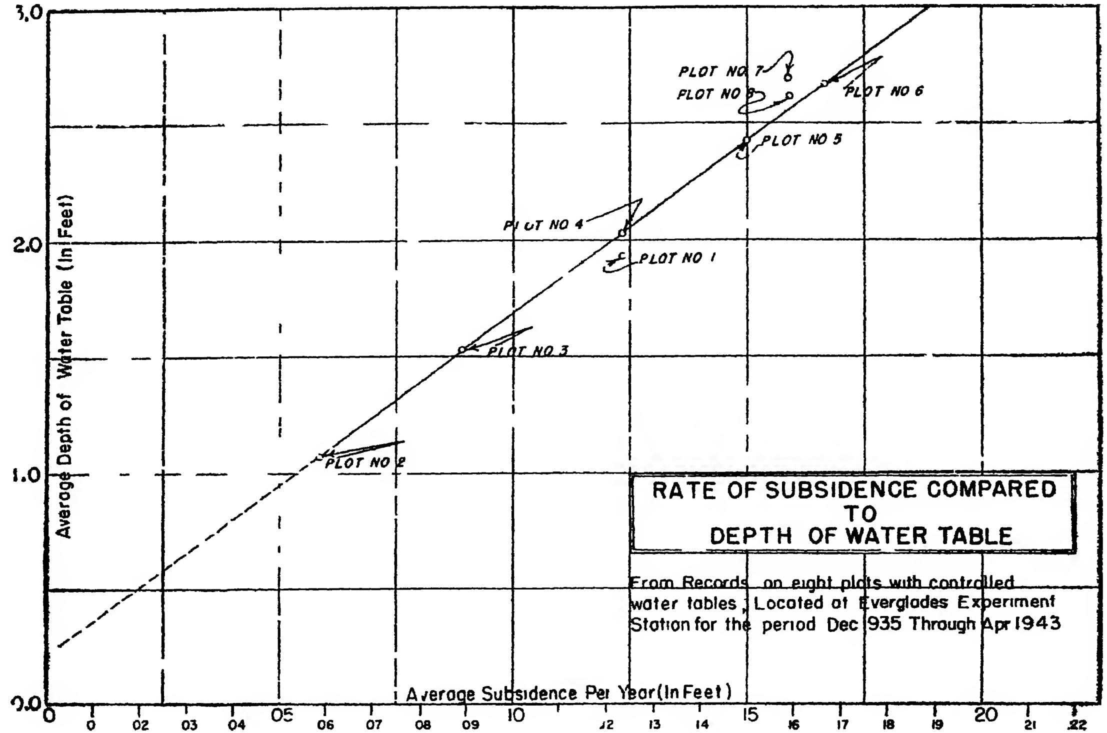


Figure 13 This shows very strikingly that the rate of subsidence for organic soils is dependent upon the depth to the water table. The higher the water table, the lower the soil loss and vice versa. Obviously the water table should be held as high as crop and field requirements will permit to prolong the life of these lands

to do best on a lower water level of 24 to 30 inches The tolerance of sugar cane to high water levels was found to vary considerably with the variety some producing better at high levels and others at low This is no doubt true to some extent with other crop varities as well

From the graph Figure 13 showing annual rate of subsidence and the preceding crop level requirements the rate of soil loss under controlled farm levels is given below

Culture	Best Water Level	Annual Loss in Inches	Years Required to lose 1 foot of peat
Pasture Grasses	(14 to 18)	3/4 to 1	12 to 16 yrs
Truck	(18 to 24)	1 to 1-1/2	8 to 12 yrs
Corn	(24 to 30)	1-1/2 to 1-7/8	7 to 8 yrs

On lands where seasonal crops are grown it is feasible to practice flood fallow whereby the land is covered by water during the period of no cultivation This practice has been used in the past primarily for pest control Obviously its wide spread use would add many years to the life of the peat soils

From the results of the controlled water table experiments it is believed that the rate of soil loss to be expected over the whole of the cultivated area will average *1 foot in 10 years* after the initial subsidence through compaction has occurred

AREA SUBSIDENCE STUDIES - 1912 TO 1950

Past history of subsidence in the deeper organic soils of the upper Everglades is a sad picture of misunderstanding of the problem and abuse of the soil through bad drainage practices The failure to reclaim and develop the Everglades in progressive units has resulted in great soil losses that could have been largely prevented

The early concept for the reclamation of the Everglades was the extension of the several short coastal rivers through the Everglades to Lake Okeechobee Such a plan proposed to reclaim the whole of the Everglades as well as to control Lake Okeechobee It was soon found that the control of Lake Okeechobee could not be accomplished by the Everglades canal system and other control channels were constructed leaving the original canal system to serve the Everglades lands The inadequacy of this system to prevent flooding and agricultural loss in the Everglades is well known The effectiveness of the canal system in overdraining the organic soils of the Everglades, especially the soils not used for agricultural purposes is not so well known

The most striking presentation of the effects of this overdrainage is best shown by a comparison of the original depths of organic soil with intervening periods and with the present depths While data is not complete for the reconstruction of the soil depths by short periods information was available for reconstruction by longer periods These will be discussed chronologically hereafter

The area reconstructed was the total area of organic soils within the Ever-

glades Agricultural Area as previously described This is an area of 987 square miles of the larger 1018 square miles proposed to be protected by levees and drained by primary pumping plants. Maps hereafter referred to, showing the organic soil depths at various periods of time, indicate this smaller area.

Original Soil Depths - 1912.

It is assumed that before the construction of the Everglades canal system by the Everglades Drainage District, the organic soils were at their maximum depth. Data is available from the early canal surveys to reconstruct these original and maximum organic soil depths with reasonable accuracy. These depths of organic soil to underlying rock or mineral soils are shown on Figure 14.

It will be noted that the organic soil depths ranged from 5 feet near Miami Canal at Palm Beach - Broward County Line - to 17 feet near Lake Okeechobee north of West Palm Beach Canal. Depths of soil decreased generally from north to south, feathering out along the mineral soil borders of the Everglades. Generally, the deeper organic soils of the Everglades fill the old floodway channels along the east and west margins.

Intermediate Period After Drainage - 1925.

By this time, more data are available from which to reconstruct the soil depths in the area. Everglades Drainage District had compiled a topographic map showing the contours of the area based on the data obtained from the surveys connected with the construction and proposed expansion program of the canal system. The Department of Agriculture was well along with the studies on subsidence lines, adding valuable spot information on soil elevations and depths. The organic soil depths at this period are shown on Figure 15.

The major change since the beginning of drainage was a general subsidence of the whole area. The definite subsidence valleys along the arterial canals were not as well defined as in later years in most instances.

Intermediate Period After Drainage - 1940.

The surveys of the Soil Conservation Service, previously described, resulted in the most complete topographic map to this date. These surveys also provided a contour map of the underlying rock and mineral soils. These elevations were the basis for the reconstruction of the soil depths as applied to earlier surface elevation data. Soil depths in 1940 are shown in Figure 16.

The subsidence valleys so evident along the drainage canals were more pronounced during this period than they probably will be again. The area as a whole continued to subside but the effects of overdrainage was being emphasized along the canals. More of the area was being cultivated, making greater demands upon drainage that resulted in excessively low canal regulation.

The Present Period - 1950.

Surveys by the Corps of Engineers in connection with investigations for the works of the current flood control plan supplied the information for the determination of soil depths at this period. They also confirmed the underlying rock and mineral soils elevations reflected by earlier surveys. Figure 17 shows the present depth of organic soil.

It is notable that the general loss for the past ten years has been approximately one foot. Drainage regulation during this period was not as favorable to

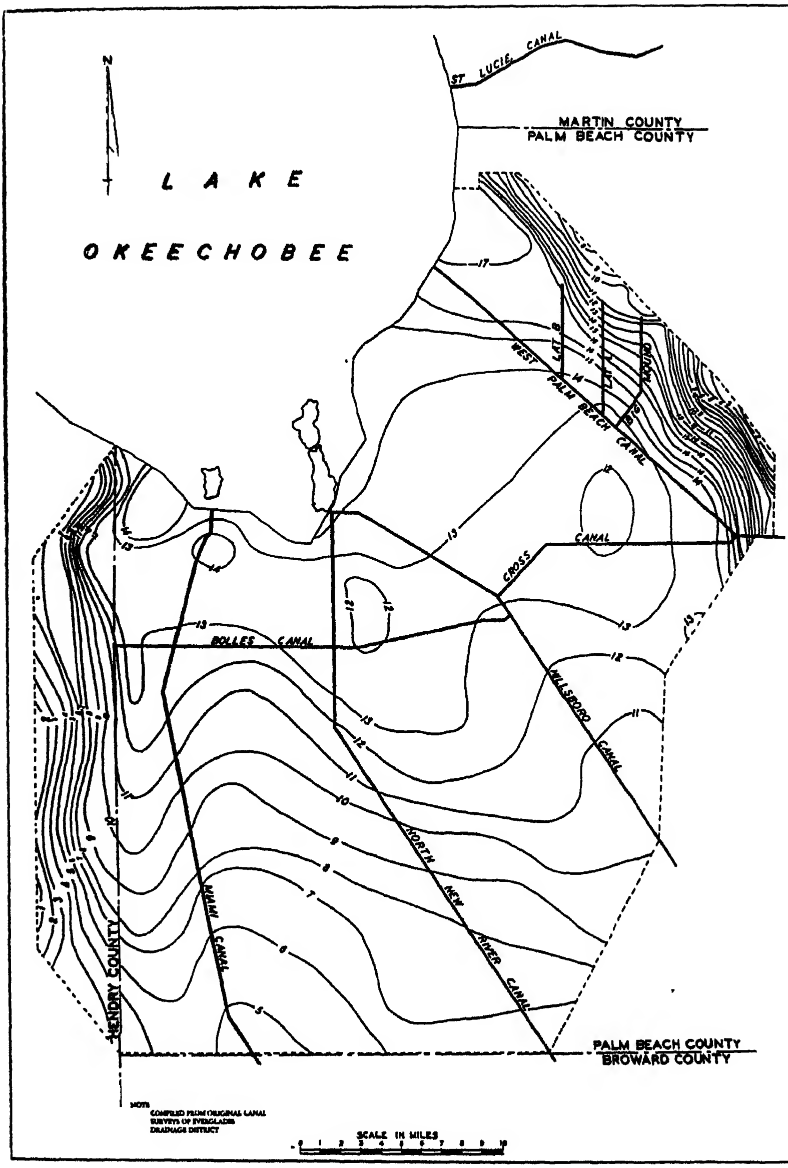


Figure 14. Map of the Everglades Agricultural Area showing the depth of the peat and muck soils in the year 1912 prior to drainage. Depth of underlying material is shown in feet.

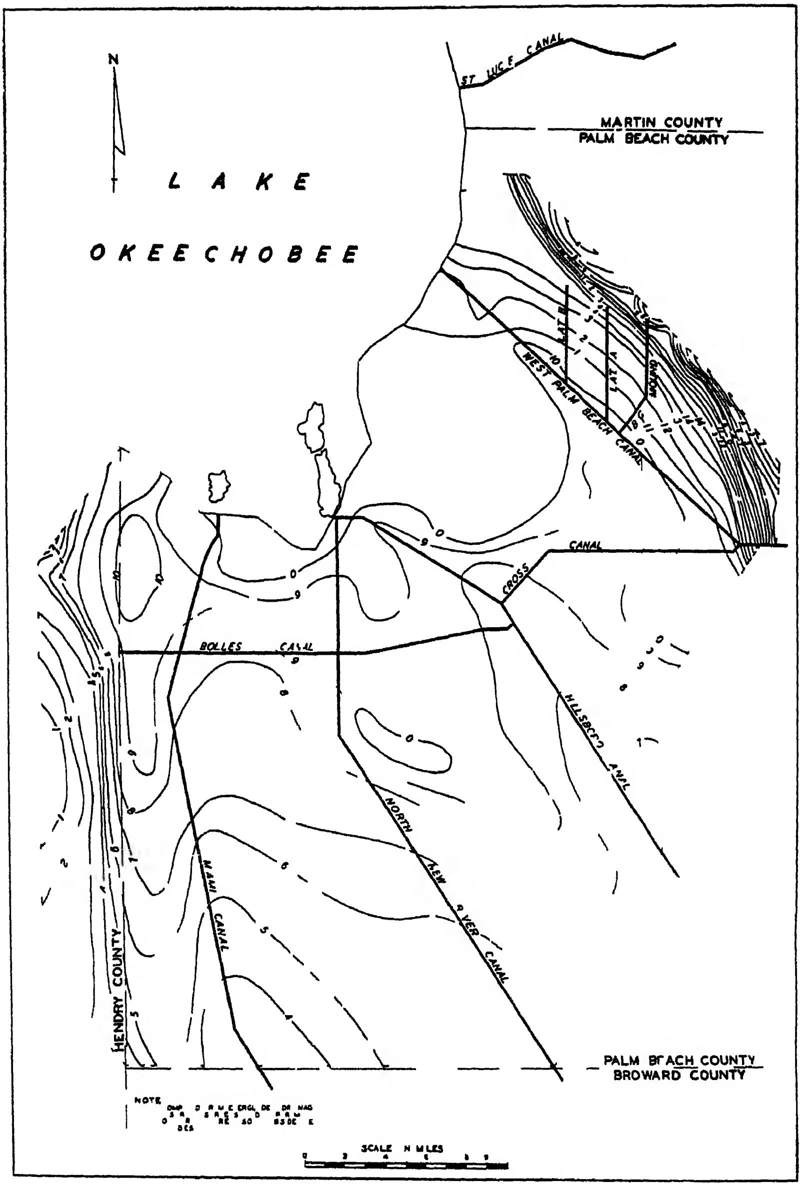


Figure 15 Soil depths for the year 1925, the intermediate period after drainage is shown

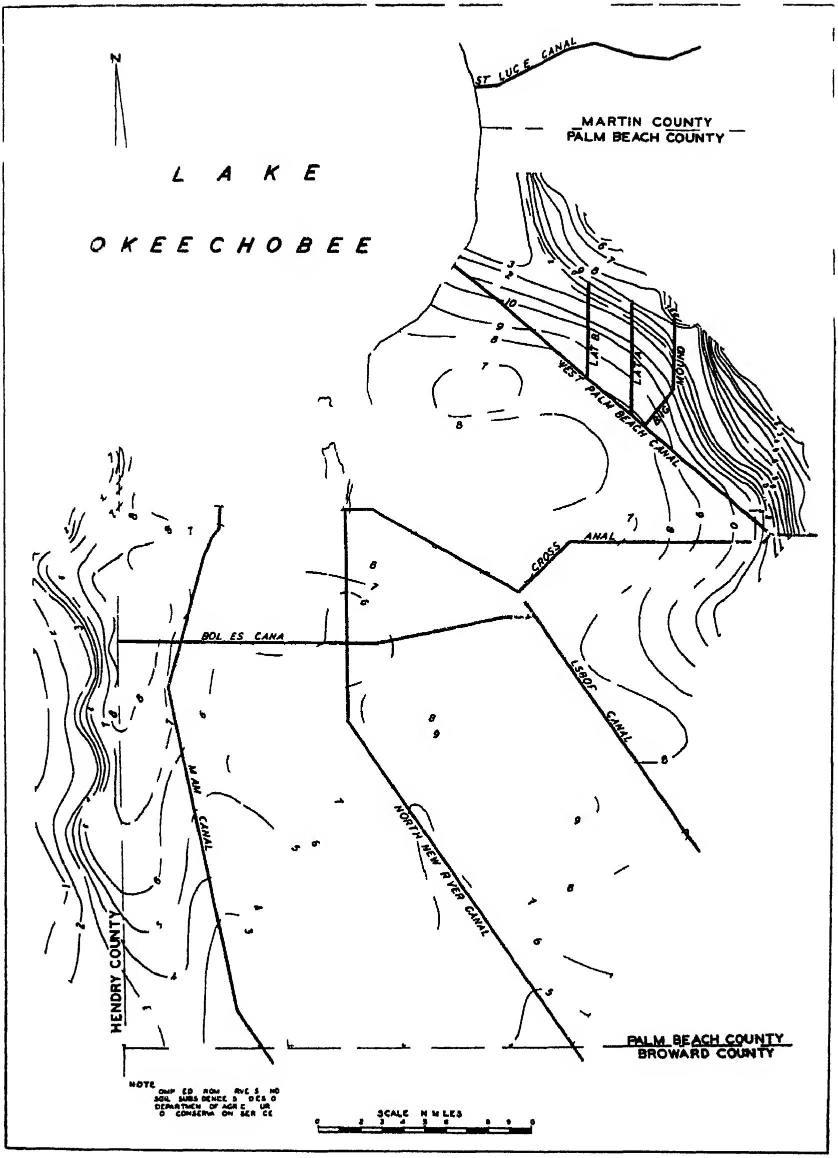


Figure 16 Soil depths in the area as shown by the surveys of the Soil Conservation Service in 1940

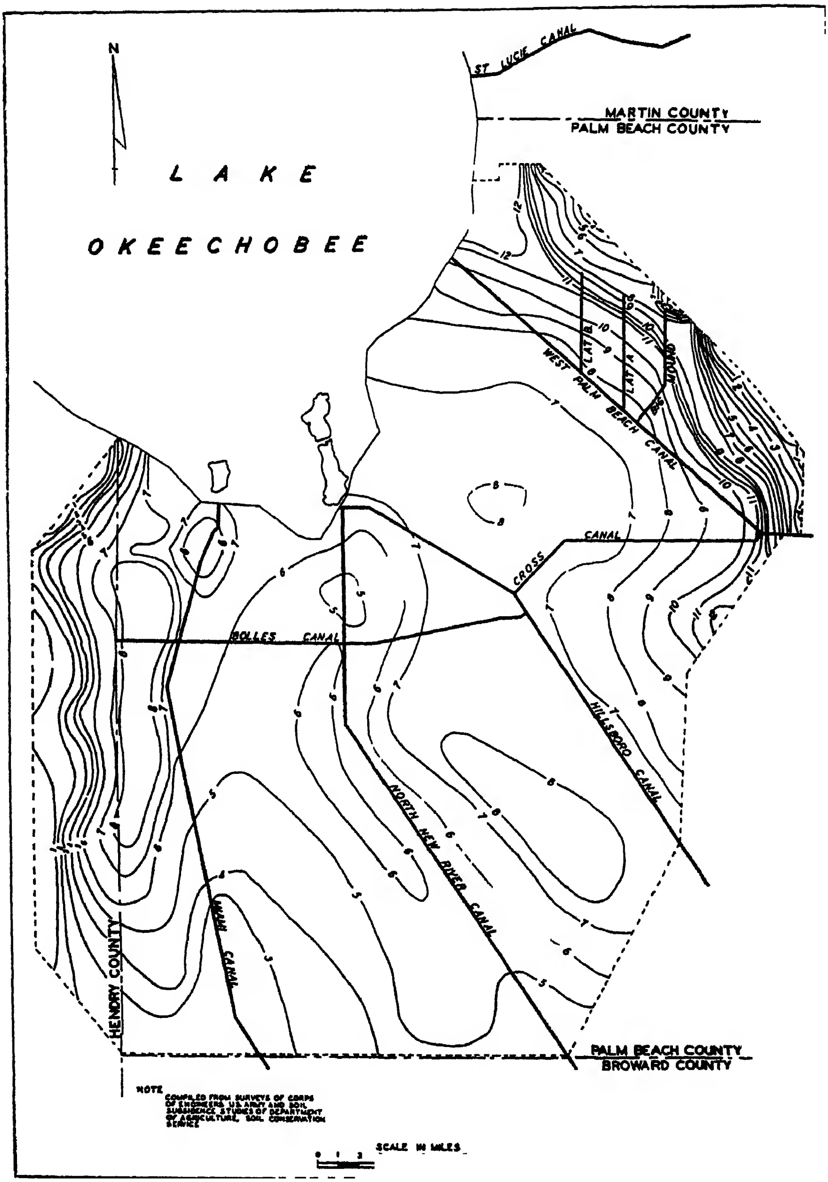


Figure 17. The present period - 1950. This map prepared from recent surveys shows a total loss in soil volume within the studied area of 40 percent since drainage in 1912.

the conservation of the soil as desirable, but, particularly during the latter half of the period, a conscientious effort was made to hold water levels as high as practicable in the arterial canals during the dry seasons within the limits possible using existing control structures. Many farmers and ranchers were becoming conscious of the relationship of water tables to soil losses and, with improved local drainage facilities were losing their fear of flooding under normal conditions that in past years had influenced the practice of overdrainage as a crop protective measure.

The subsidence valleys along the arterial canals are not quite as pronounced as in 1940, probably due to generally higher regulation of the arterial canals in the dry seasons during this period. However, soil losses in the higher undeveloped lands between the canals continued at about the expected rate. The ominous part of the present picture is the evident creeping northward, from the southern boundary of the area, of the spreading range of shallower soils that do not justify development for long term use

Summary of Area Subsidence from the Original Condition to the Present

Forty years of almost uncontrolled drainage and development has taken its toll of the organic soils of the Everglades Agricultural Area. Of the original depth, approximately three feet has been lost in the vicinity of Miami Canal; seven feet has been lost from the area near Bolles and North New River Canals; and five feet from the deep peat area north of West Palm Beach Canal near Lake Okeechobee. The total volume in the studied area has decreased by 40%.

The losses in the undeveloped lands have occurred to almost the same degree as in the lands in cultivation. Fires have been a contributing hazard in the wild lands where they were very difficult to successfully combat. It is apparent that a continued loss from both cropped and undeveloped lands is inevitable under present and foreseeable land use and water control practices. As heretofore stated, the average probable rate of loss will be approximately one foot in ten years.

The certainty of continuing soil losses in the organic soils of the Everglades must be squarely faced. In order that the facts pertaining to the future of the area be available for the general information of the public, it is believed desirable to project the subsidence picture into the future. This will be presented hereafter, based on the known factors influencing subsidence, assuming certain conditions of land development and use.

PREDICTED SUBSIDENCE - 1950 to 2000

Based on the known factors of subsidence, the future of the organic soils, as to their years of usefulness, can be estimated with reasonable accuracy. The subsidence picture will be extended by ten year periods to the year 2000 A.D., beyond which period the value of such extension will be apparent.

The Near Future Period - 1960.

It has been assumed that by 1960 the entire Everglades Agricultural Area will be under dike and pump and developed for agricultural purposes. By using this assumption, the lands now in use and under pump should continue to subside at the average rate of one foot in ten years. However, the present area of wild lands, assumed to be placed in cultivation by 1960, will take an initial subsidence of approximately six inches soon after being placed in cultivation

in addition to the normal rate, or a total of about eighteen inches for the 10 year period. This initial loss, inevitable in converting wild land to agricultural use, was taken over the entire area prior to 1960 to simplify long range projection of the subsidence losses. Regardless of when this initial loss is taken, the end result is the same.

By the end of this period the area of lands having only short term agricultural use is noticeably spreading northward into the heart of the area. The margins of peat soils lying over mineral soils is shrinking toward the center of the organic soils area. The area, as a whole, by 1960, however, is still largely capable of sustaining long term agriculture and the growing of crops requiring mole drainage practices. The soil depths at this period are depicted on Figure 18.

The situation mentioned above, of the shrinking of the organic soils from the mineral soil margins of the Everglades, is not a serious factor. Where these mineral soils have depth, their continued use and productiveness is almost unlimited. It is where the organic soils are immediately underlain by rock that subsidence is the determining factor of the length of the land's productiveness.

As the organic soils over rock become shallower, there will be the necessity of deepening the farm drainage ditches into the rock. This is believed to be entirely within the economics of the land's productiveness. However, when the organic soil has subsided to a point where it does not have sufficient depth to permit mole draining, it can only be used for more water tolerant crops. The soil use under these conditions may still be economically feasible. When the soil depth has subsided to only one foot above rock, it is questioned that this depth of soil over dense rock can be maintained below the saturation point sufficiently to be used economically. Further, a real difficulty will arise when the necessary water table for a particular crop falls below the surface of the rock when the supply will be lost by capillarity to the peat.

Successive Future Intermediate Periods - 1970, 1980 and 1990

These periods have been treated as a group because there is no particular reason to differentiate between them. The area continues to subside as a whole and the margins over mineral soil to shrink inward. These several periods are shown on Figures 19, 20 and 21

By 1990, much of the area will probably be too shallow in soil depth to support an economical agriculture. A larger part will be of such shallow depth that mole drainage will be impracticable and agricultural use will be limited to pastures and water tolerant crops. The organic soils suitable for so-called long range development will be restricted to a small area north of the West Palm Beach Canal and a small acreage along the narrow rim of higher mineral soils that border Lake Okeechobee.

The Period - 2000

By this time most of the Everglades Agricultural Area will have subsided to a degree where it is doubtful that economical agriculture can be supported generally. Some agricultural use on a normal scale will still be possible on small areas north of the West Palm Beach, south of the Cross Canal and near the rim of Lake Okeechobee. The detailed contours showing this small area bordering Lake Okeechobee does not appear on any of the plates of the Everglades Agricultural Area as it is too small to be shown at the scale of the plates.

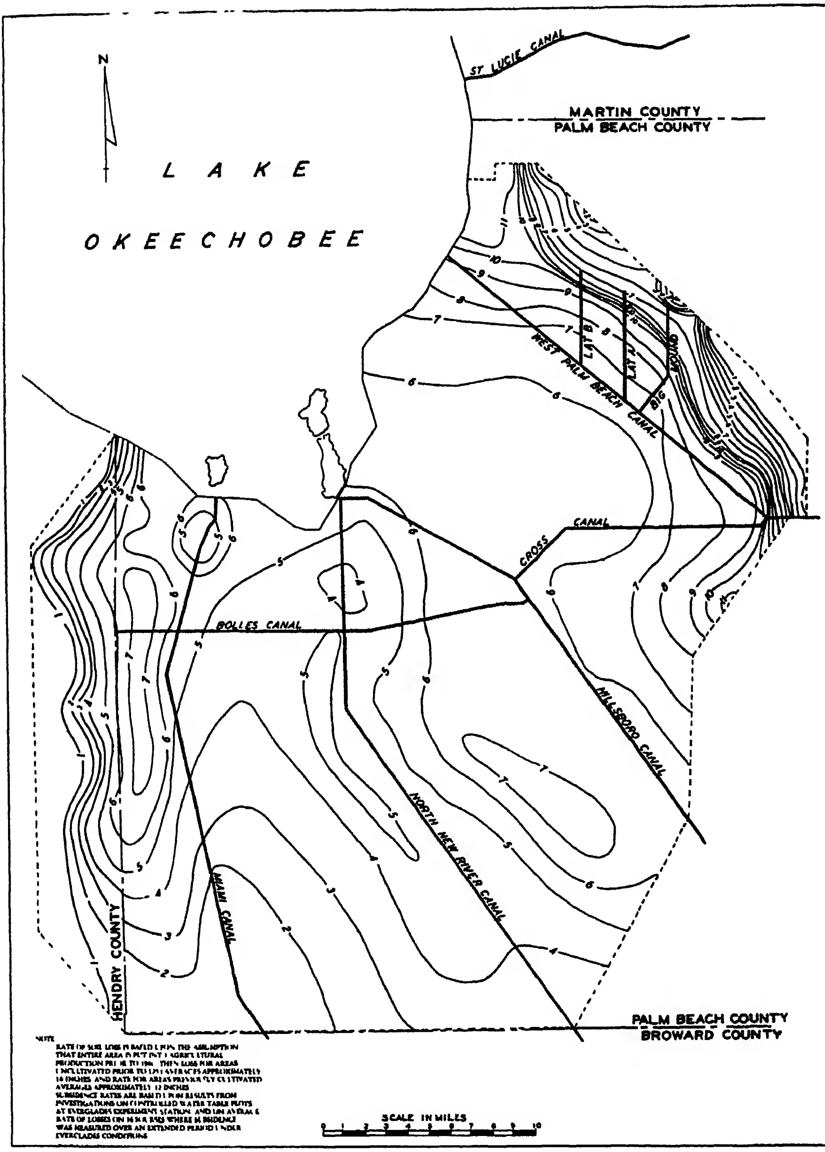


Figure 18 Predicted soil depths for 1960. The following group of maps show the probable depths of organic soil which will remain as subsidence continues in accord with the rates outlined in the text

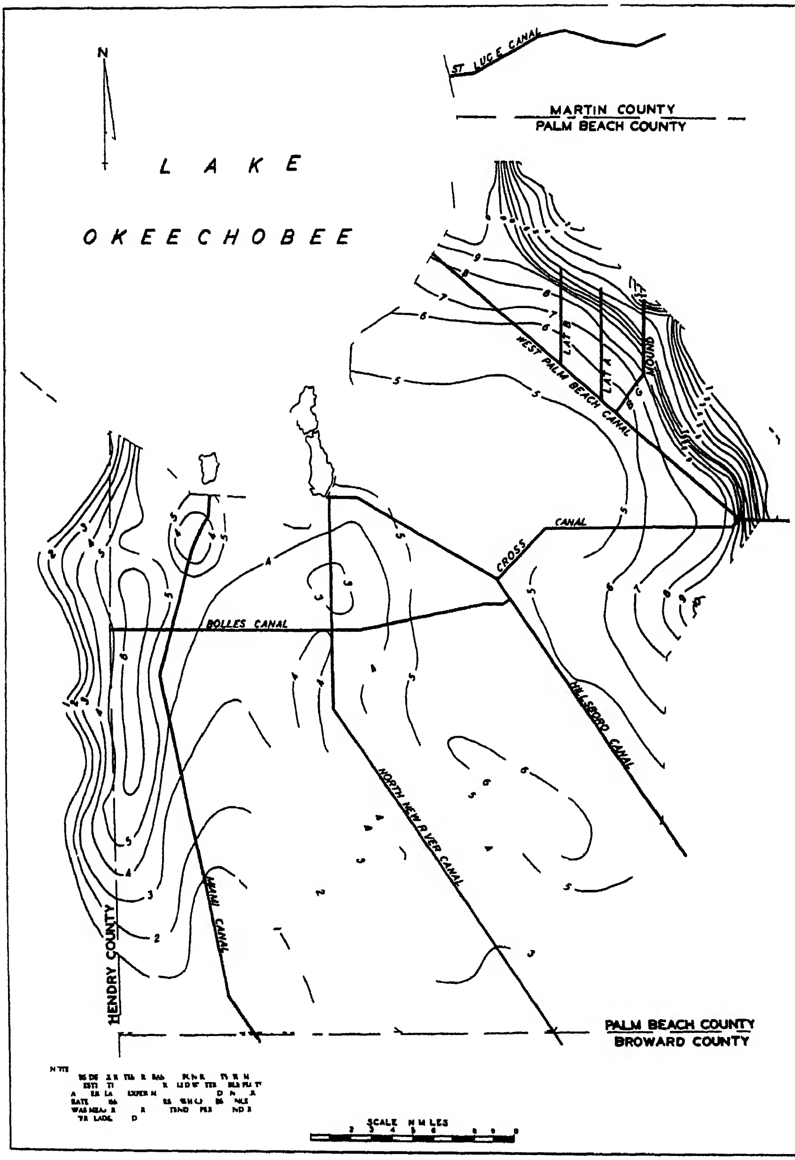


Figure 19 Predicted soil depths for 1970 The soils will continue to subside so that a large part of the area will be unsatisfactory for mole drainage which requires peat soils in excess of 3 ft depth

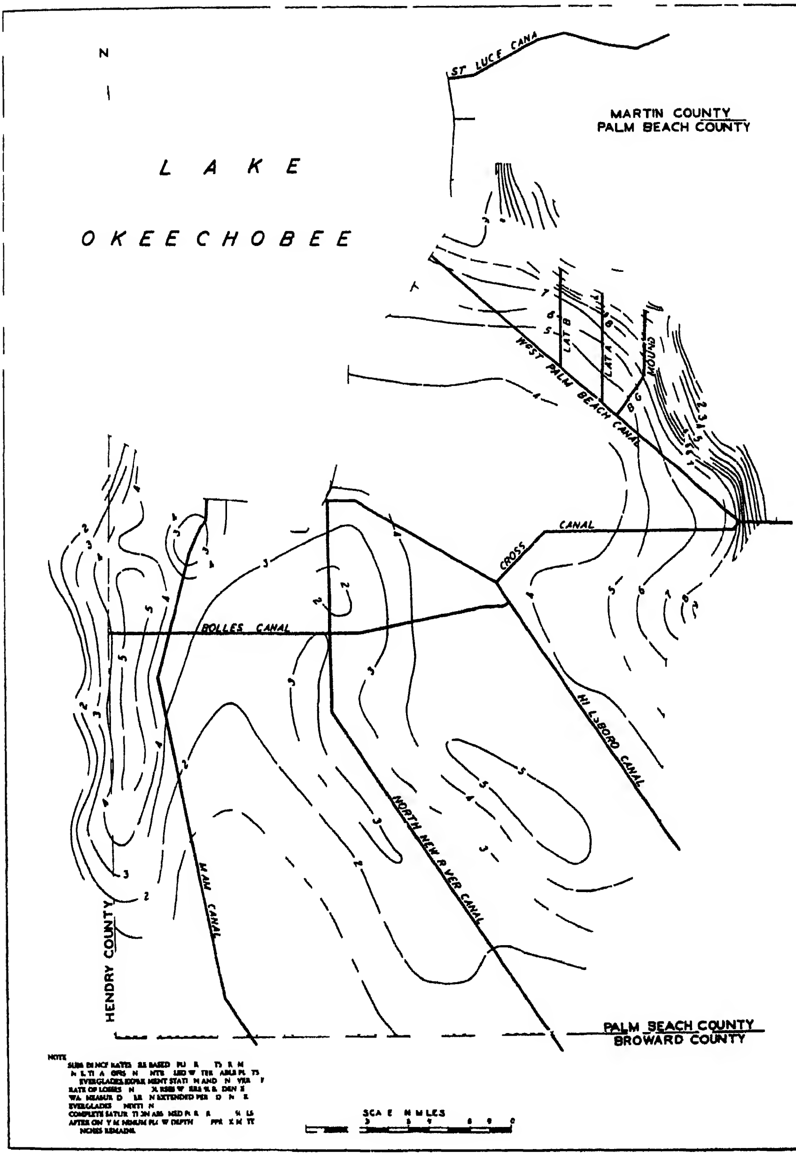


Figure 20 Predicted soil depths for 1980 The soils will continue to lose depth as a whole and the margins over mineral soils will shrink inward noticeably A good portion of the area adjacent to the lower Miami Canal will probably already be below plow depth

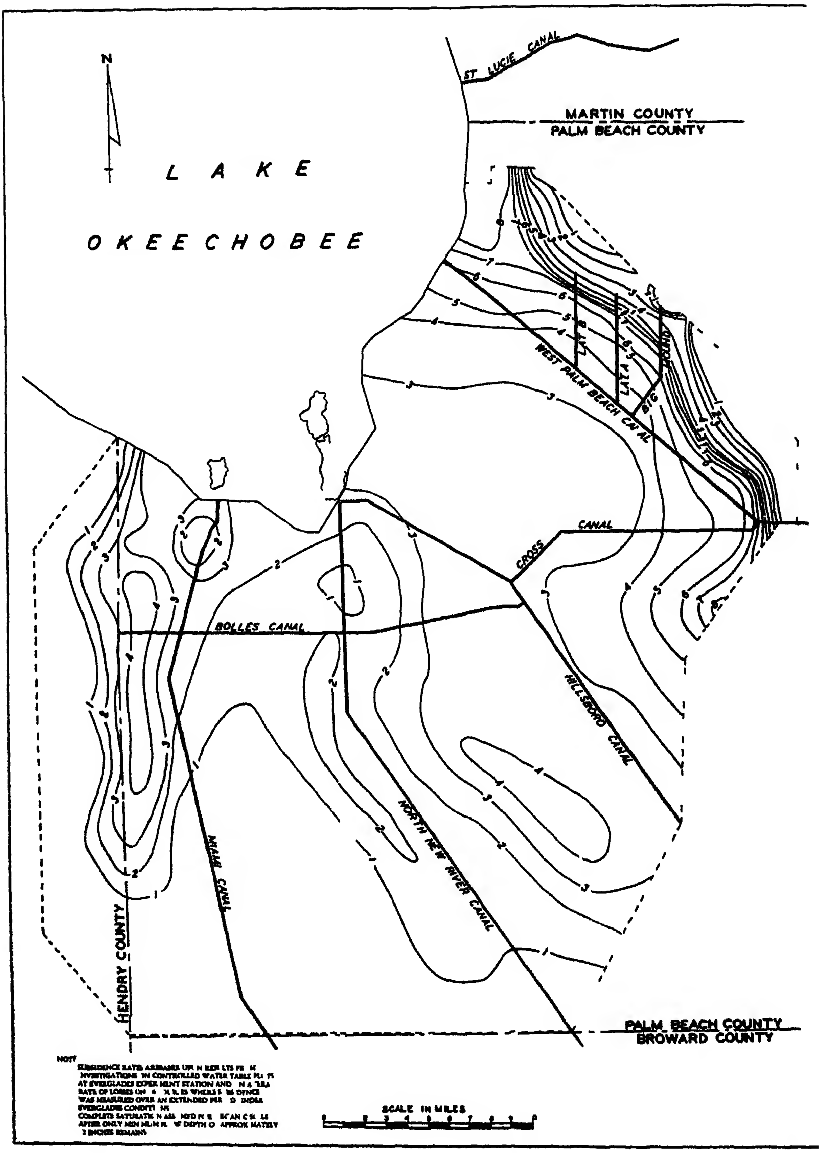


Figure 21 Predicted soil depth - 1990 A considerable part of the area will be so shallow in depth that agricultural use will be limited to pasture and water tolerant crops, and a large part will be too shallow to support an economical agriculture.

Figure 22 shows the estimated soil depths of the Everglades Agricultural Area in the year 2000 It is evident that by this time a large part of the area will have been abandoned This abandonment of large areas may increase the problems on lands still struggling to produce crops and may hasten the abandonment of practically all of the central part of the area It is almost certain by this time that it will not be economically feasible to have water control of the whole of the area which is also a factor contributing to final abandonment

Summary of Area Subsidence from the Present Date to 2000 A D

It is unquestionable that, in the light of expected subsidence and probable land use practices the agricultural life of the organic soils in the Everglades Agricultural Area will be almost ended by the year 2000 An aroused consciousness of the seriousness of the problem and better maintenance of water table practices may somewhat add to the soil life locally, but in general, large scale abandonment by approximately the year 2000 is the logical result that can be expected

SUMMARY DISCUSSION OF SUBSIDENCE

Observations and analyses of area subsidence, subsidence lines and controlled subsidence plots definitely prove the certainty of soil loss associated with agricultural use of organic soils or non-use of those soils, if drained and the relationship of the ground water table to that loss Accepting these losses, it is timely to review the effects and plan future land use practices

Figure 23 shows the location of typical cross-sections of the area which are shown on Figures 23 and 24 Study of Figures 23 and 24, indicates that as a whole the peat soils have subsided at a more or less uniform rate This same pattern of subsidence may be expected in the future Analyzed for periods of thirty years, as shown on the figures referred to above, the approximate total loss in cross-sectional area from the original for each period is as follows

1912	None
1940	32%
1970	66%
2000	88%

With continued subsidence, the remaining soil will be of a somewhat greater density than the original However, as most peats of the Everglades are of low mineral content, this increase of the soil density will have little effect on the total subsidence at least to the point where agriculture is impracticable

With continued loss in surface elevations the problems of water control increase When organic soils shrink to less than three feet of depth, mole draining becomes impracticable Thereafter, land use will be restricted to crops having a greater tolerance to water The loss of soil elevation creates problems of drainage Surplus water from farms must generally be discharged against increasingly higher stages of the main drainage canals that are presently more or less fixed in their regulation This same condition tends to increase seepage that must be combatted by the farmer in providing water control for his lands

The depth of organic soil controls the economic use that can be made of the

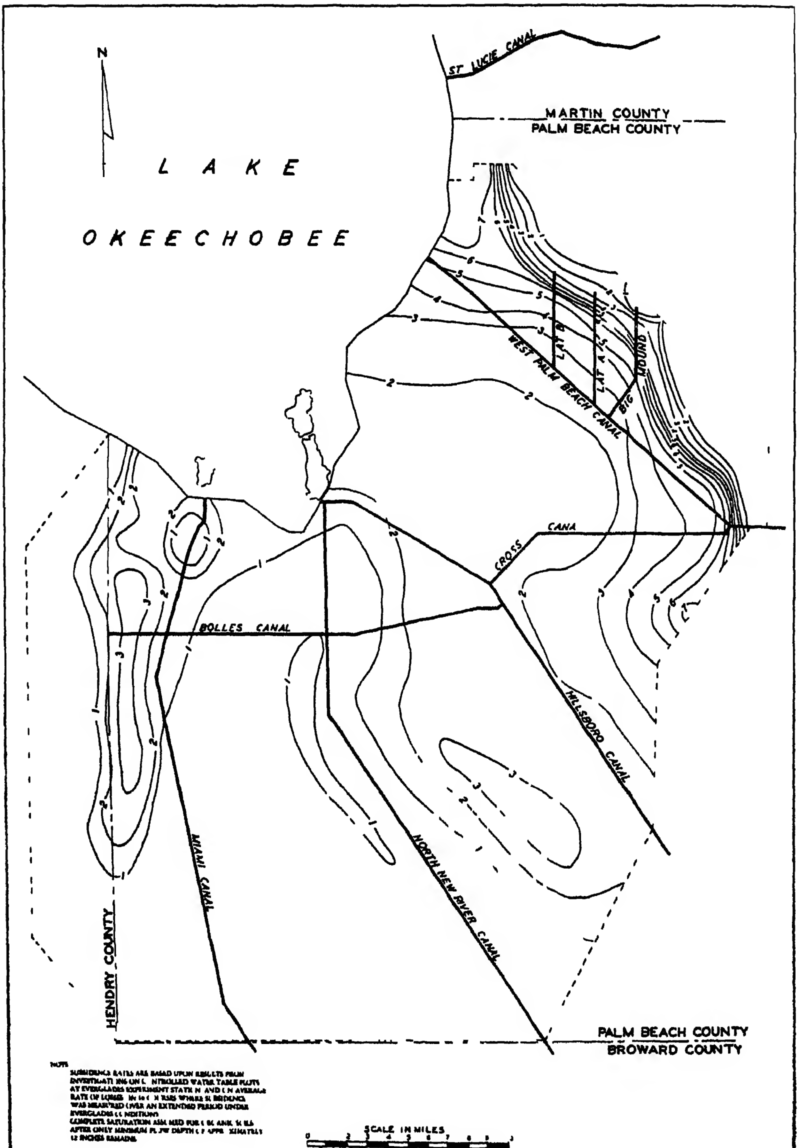


Figure 22. Predicted subsidence - 2000 A.D. By this time most of the Everglades Agricultural Area will have subsided to the point where there will probably be wide scale abandonment over much of the area. Water control problems on the remainder of the area will be intensified.

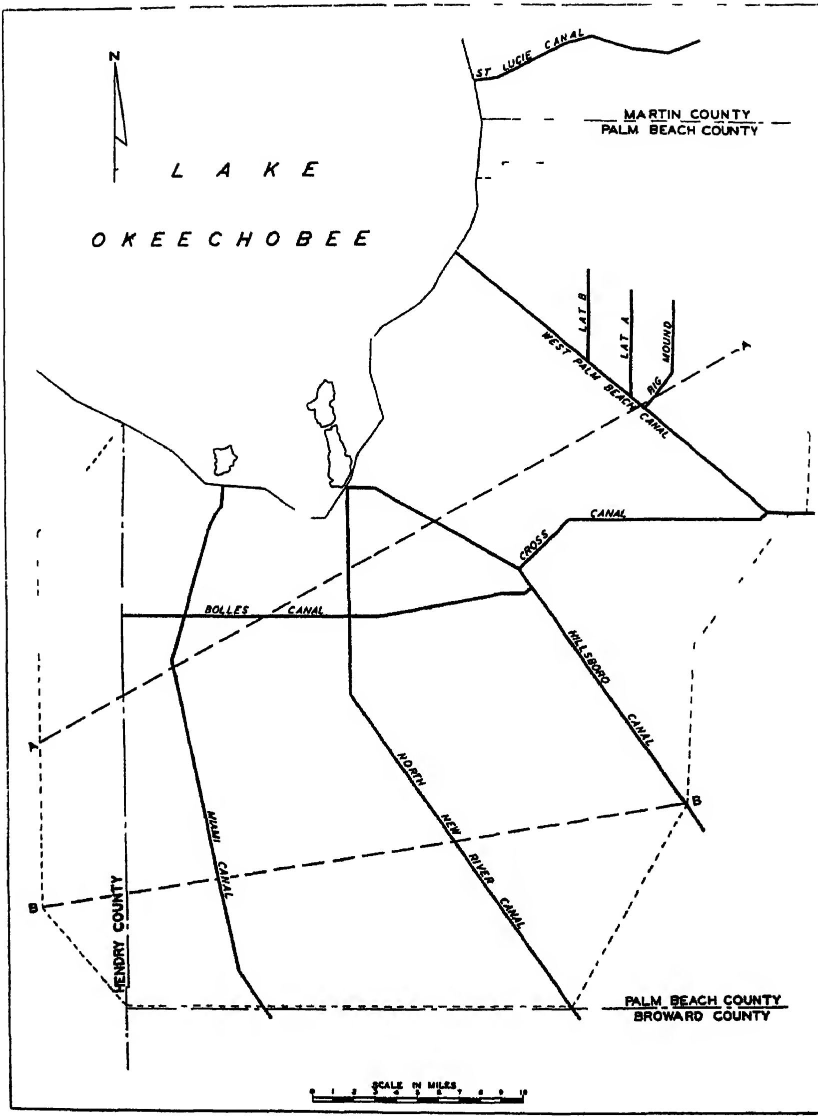


Figure 23. Map of the Everglades Agricultural Area showing the location of cross-section "A-A" as shown in Figure 24, and of cross-section "B-B" as shown in Figure 25.

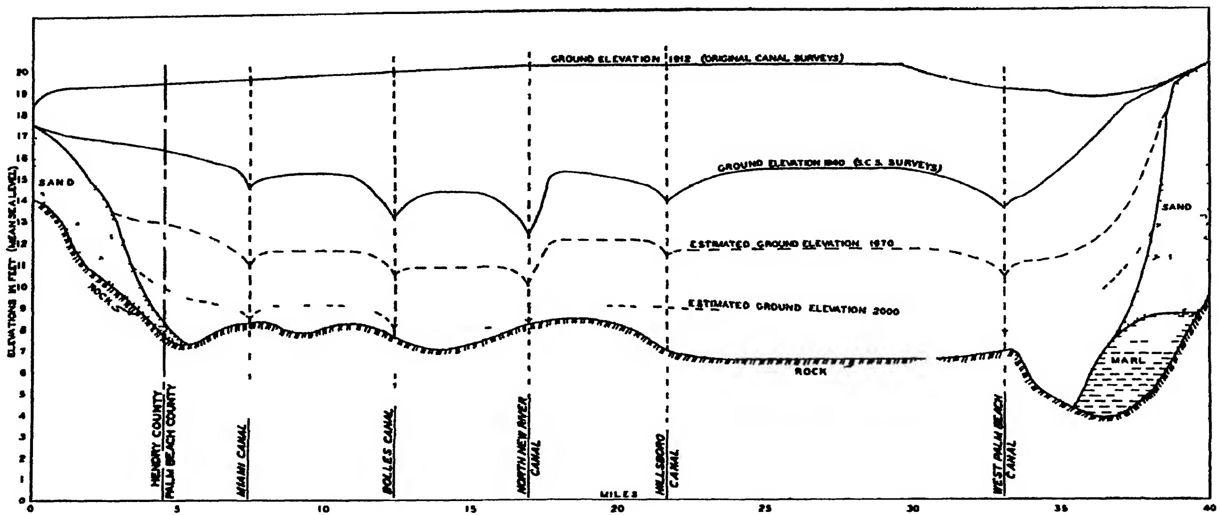


Figure 24 Cross-sectional view through the upper Everglades along line "A-A showing original surface elevations, and the elevation in 1940 as shown by topographic surveys Estimated ground elevations for the year 1970 and for 2000 A D are also shown

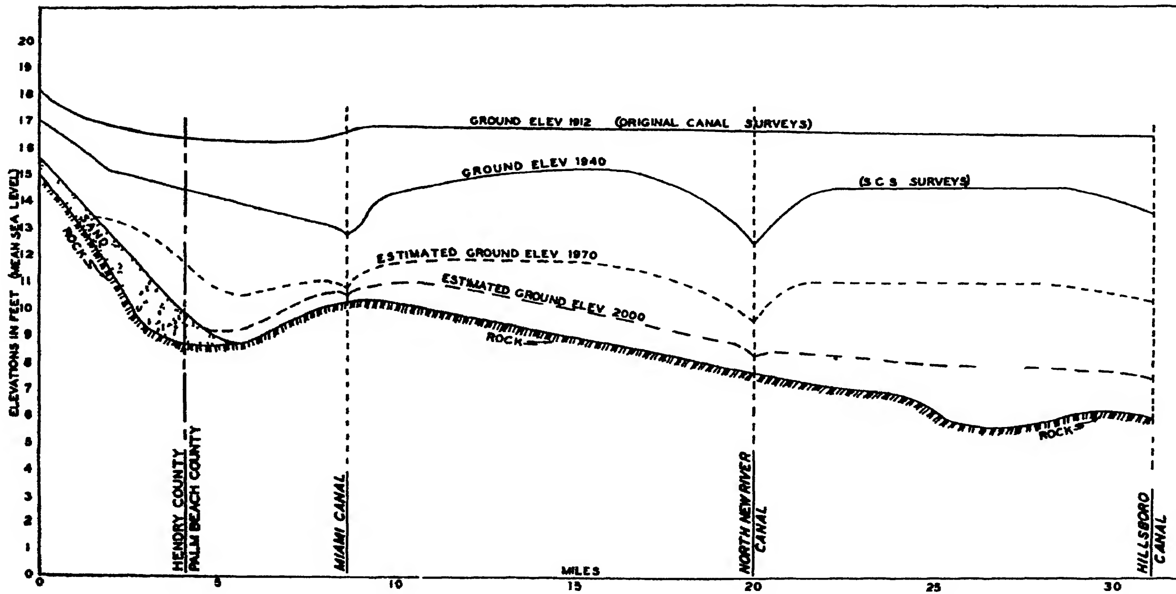


Figure 25. Cross-sectional view through the lower part of the Everglades Agricultural Area along line "B-B". From sections "A-A' and 'B-B" it was found that the total loss in sectional area from the original was approximately 32 percent to 1940. It is estimated that the total loss will be 66 percent by 1970, and 88 percent by 2000 A D

land. It is questionable if extensive development for long time use is justified in land where the virgin soil is less than 5 feet in depth. The economic justification for development of raw lands of less than 3 feet in depth where initial subsidence must be taken, to the extent of even limited excavation of ditches into rock, is doubtful. The value of future markets for Everglades farm products and future cost of development may well be the controlling factor in the use and extent of use of Everglades lands in the later periods.

As mentioned heretofore, it is considered impracticable to mole drain organic soils of less than 3 feet depth. Everglades peat soils of a deeper depth are readily adaptable to mole draining operations and practices within limits, and the cost is nominal. The justification of providing tile drainage in soils too shallow to mole drain has not been determined, but is not believed to be economically feasible except perhaps for special crops. It is not believed that soil less than 1 foot depth can be used economically for agricultural purposes.

Classifying the soils of the Everglades Agricultural Area according to land use and development justification, by periods represented by Figures 14 to 22 inclusive, the following table has been prepared:

PERCENTAGE OF TOTAL ORGANIC SOILS

	Depth in ft.			
Year	0.0 to 1 0	1.0 to 3.0	3.0 to 5.0	Over 5.0
1912	0.1	1.2	3.4	95.3
1925	0.6	3.1	7.8	88.5
1940	0.8	6.8	7.2	85.2
1950	1.7	6.7	13.6	78.0
1960	4.4	12.4	28.1	55.1
1970	10.7	16.2	27.8	45.3
1980	16.6	28 4	41.3	13.7
1990	27.0	28.2	37.8	7.0
2000	45.3	42 2	8.8	3.7

To obtain the maximum benefits from the organic soils of the Everglades Agricultural Area, the following objectives should be considered in all future planning for water control and land use:

1. That land development be predicated on the expected life of the soils and the land capability.
2. That land and water use practices be improved, where possible, to obtain the maximum productive life of the soils.
3. That the design of water control systems be such that will provide the maximum opportunity to achieve the best land use practices.
4. That all efforts be made to provide adequate water control facilities and place the organic soils in use as quickly as possible in order to forestall the wasteful loss of soils in lands not now in use.

5. That research be intensified and that the public be kept informed on the progress made on the more beneficial land use and water control practices as developed in order that everything possible may be done to conserve and prolong the remaining life of these soils.

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Mr Frederick Mertz who, as Chief Engineer of Krupp's Fiber Division for more than 50 years, made many improvements in the Corona type decorticator It was he who developed the angled drum approach which first appeared in his Krupp Viktor In response to a request for a brief history of the development of the Corona Decorticator he very kindly sent us pages 57 60 from the *Sisal Review* for August, 1938 which are reproduced on the pages that follow (239 - 242) As a background for his photograph are to be observed bales of kenaf fiber mechanically decorticated by a Mohegan Corona in the mill of the American Kenaf and Fiber Corporation Belle Glad

THE HISTORY OF THE CORONA DECORTICATOR

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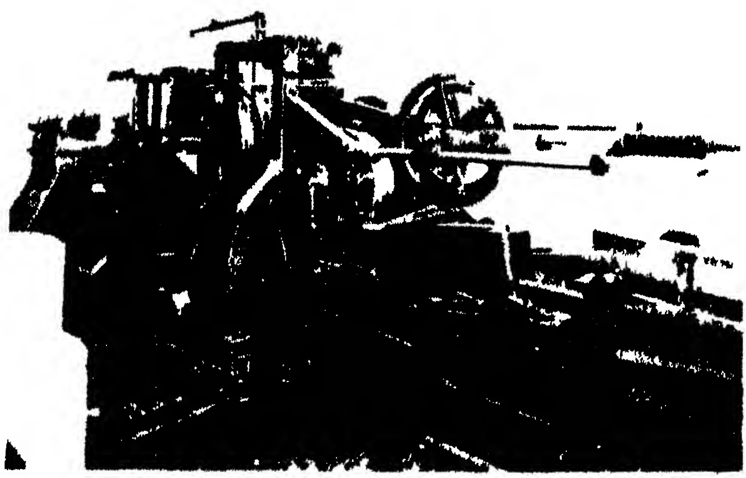


1 The Latest Corona Machine

[illegible] Corona machine is shown in [illegible] eight hours. The fibres [illegible] in the machine and stripped clean [illegible]

[illegible] maximum extraction and quality.

The idea of building Fibre Recovery Machines was first brought to Krupp by Mr. Hubert J. Fischer (Fig. 2), an engineer who,

[illegible] several [illegible]

[illegible] endeavours to find a device [illegible] usual Raspador drum, a device which strips the fibre quite gently.

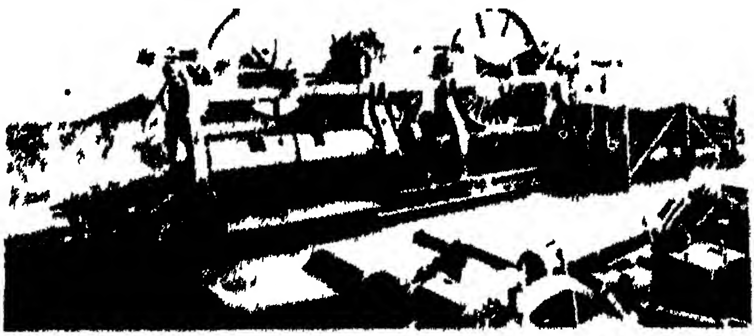
Mr Hubert J Booken

THE HISTORY OF THE CORONA DECORTICATOR (contd.)

In the year 19[illegible] the first Corona Machine [illegible] Krupp and Mr [illegible] [illegible] the machine [illegible]

[illegible] Mr [illegible] Technical Director [illegible] [illegible] the rope, etc.

[illegible] result of the [illegible] a large number of [illegible]



IV The Viktor

[illegible]

[illegible]

V The [illegible] Machine

HISTORY OF THE CORONA DECORTICATOR (contd.)

VII Containers in which Fibre Recovered was originally washed. The Fibre Recovered is now washed in the Decorticator itself.

OTHER EQUIPMENT OF NOTE FOR THE HARVESTING AND PROCESSING OF BAST FIBER CROPS THAT THAT HAS BEEN STUDIED RECENTLY

Figure 1. Hand-fed ribboning machine developed by Mr. Charles R. Short of Clermont, Florida, has high-speed rolls and clears the ribbons rapidly with virtually no fiber loss.

Figure 2. Henriquez harvester showing (front view) topping attachment mounted in an adjustable frame in front of and on side of tractor. The reel forces the tops of the kenaf plants into the horizontal conveyor which carried them over the top of the tractor and drops them at the side. The gathering and grip conveyor (side view) is shown at the rear of the tractor. This unit is mounted on a standard mowing machine. The harvested stems are deposited in a continuous windrow on left of the tractor.

Figure 3. Henriquez ribboner, "V" pattern, double drum type with feed table and single-grip conveyor which forces the stalks into and removes the ribbons from the opposed "bottom" and "tip" drum-type beaters. The angled arrangement of the drums gives a progressive cleaning towards the center of the stems. Unfortunately the central section of the stalks held continuously within the gripping device is not cleaned in the present development of the unit.

THE FIRST MEETING OF THE U.S.D.A. KENAF FIBER GRADING COMMITTEE

1951

The first meeting of the U.S.D.A. Fiber Grading or Typing Committee for kenaf was held at the Everglades Experiment Station on the morning of November 1st and continued through the entire day with a special field trip to the mill of the American Kenaf and Fiber Corporation in the afternoon.

A good supply of fiber representing the full scale of quality being produced at the time was made available for study. Four tentative types or grades were set up during the day subject to change as the study continued on into the future. Several sets of samples representing all four grades were prepared but a sufficient amount of the top grade was not found to bale and find a place in commercial handling. As a result of this fact at a later meeting of the Grading Committee (Nov. 21, 1951) these three grades, Nos. 2, 3 and 4 were finalized for the 1951 crop and numbered 1, 2 and 3 but still represented only Medium, Fair and Low types or grades of fiber, respectively.

The committee was continued with the substitution on it of Mr. Ralph J. Blank, Vice President, American Kenaf Fiber Corporation for the

Figure 1. Members of the Fiber Grading Committee from left to right, with E. D. Bell, Deputy Director, Cotton Branch of the Production and Marketing Administration, U.S.D.A., Washington, at the far right: Walter R. Guthrie, Lehigh Spinning Company, Allentown, Pa.; Elton G. Nelson, U.S.D.A., Beltsville, Md.; H. C. Slade, Standardization and Appeals Section, Cotton Branch, P. & M. A., U.S.D A., Washington; Alexander L. Guterma. American Kenaf and Fiber Corp., New York City.

President of that Corporation, Mr. A. L. Guterma. The only known source of official information on the deliberations of the Committee is the files of the Cotton Branch. P. and M. A., U. S. Dept. Agriculture. Mr. E. D. Bell, Deputy Chief.

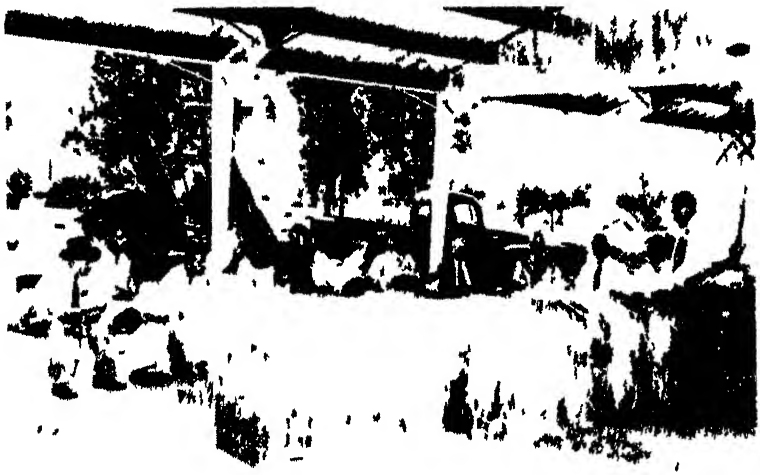


Figure 2. The Fiber Grading Committee in general session, left to right R. A. Colyer, Australia; J. M. Dempsey, Canal Point; R. J. Blank, West Palm Beach; Geo. R. Boyd, U.S.D.A., Washington, D. C.; A. L. Guterma, New York City; Elton G. Nelson, U.S.D.A., Beltsville; Walter R. Guthrie, Allentown, Pa., H. C. Slade, U.S.D.A., Washington, D. C.; Clovis D. Walker, U.S.D.A., Washington, D. C.; Wilson C. Tucker, U.S.D.A., Washington, D. C.; S. M. Kimball U.S.D.A., Atlanta, Ga., E. D. Bell, U.S.D.A., Washington, D. C.

Figure 3 Members of the Fiber Grading Committee and others at the plant of the American Kenaf and Fiber Corporation's plantation southeast of Belle Glade, left to right Dr A G Peterson Munitions Board Dr C H Schoffstall National Production Board, Mr H C Slade, U S D A , Mr E D Bell (head turned), U S D A , Mr Walter Guthrie Allentown Pa , Mr E G Nelson, U S D A , Mr Wilson C Tucker U S D A Mr A I Guterma President of the American Kenaf and Fiber Corporation